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## ERRATA.



## Page

225, line 13 from bottom, for *Calocalanus pergens* read *Clausocalanus pergens*.

487, lines 14, 22, 24, for *agglomerata* read *agglomeratum*.

535, „ 4 and 8 from bottom, for *brevispinus* read *brevispina*.

542, line 4 from bottom, for *juglandifolius* read *juglandifolia*.

544, „ 8, for *L. mexicana* read *Sira mexicana*.

## EXPLANATION OF THE PLATES.

## PLATE

- 1-2. *Cubaris secutor*, sp. n.
- 3. The Carboniferous Scorpion *Eobuthus* Fritsch.
- 4. Anthuridæ.
- 5-10. Biscayan Copepoda.
- 11. *Pionocypris vidua*.
- 12-13. *Ainigmaptilon haswelli*.
- 14-16. *Shumardia pusilla* (Sars).
- 17-21. Victorian Tertiary Foraminifera.
- 22-23. *Chirocephalus diaphanus*.
- 24. Anplexus of Common Frog.
- 25-29. Relation between Egg-weight and Body-weight in Birds
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- 35-39. Coral Reefs of Tahiti, Moorea, and Rarotonga.
- 40-44. Some Recent Crinoids.





# THE JOURNAL

OF

## THE LINNEAN SOCIETY.

### (ZOOLOGY.)

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Some Protozoa from the Soils collected by the 'Quest' Expedition (1921-1922). By H. SANDON, M.A., and D. W. CUTLER, M.A., F.L.S.

[From the Protozoology Dept., Rothamsted Experimental Station.

[Read 6th March, 1924.]

DURING the recent voyage of the 'Quest,' Captain Wilkins very kindly collected a number of samples of representative soils for the purpose of protozoological examination. The samples were taken in previously sterilized, tightly-fitting tins so that there was no possibility of contamination.

The method of examination consisted in putting small quantities of the soil into various culture media, which were then incubated and examined at intervals for about one month. The media used were nutrient agar, which seems to be the best medium for most of the flagellates and smaller amœbæ, hay infusion which is rather better for some ciliates, and tap-water for the testaceous rhizopods and for some of the ciliates and larger amœbæ which do not thrive in the more concentrated media.

The samples were necessarily small (owing to the exigencies of space on board the 'Quest'), and consequently no physical or chemical analyses were made in order to attempt to correlate the protozoal faunas of the soils with their other properties. This omission, however, was probably of little importance, as observations on other soils from stations varying considerably in climate have failed to reveal any simple connection of this kind. Capt. Wilkins, however, provided some useful meteorological and geological data with respect to the soils, which are incorporated in the following notes.

*St. Paul's Rocks.* Sample 1.

This minute and remote island in the S. Atlantic bears no vegetation apart from marine algæ. Sea spray at times washes right over the island. The loose gritty "soil" (if such a name can be applied) contained a good deal of animal matter (dead insect larvæ, fragments of cuticle, wings, etc.), and is no doubt enriched by the sea birds nesting there. The rocks are semi-metamorphic picrite. The sample was taken at a height of about 20 feet, and the temperature in the shade at the time (Nov. 1921) was 82° F. In spite of the abnormality of the conditions, a varied protozoal fauna was found, including most of the commonest soil forms.

*South Georgia.* Samples 2-7.

South Georgia is a group of mountainous islands situated in Lat. 54° to 55° S. at a distance of about 1200 miles from S. America. The climate is damp and foggy, with a temperature ranging between 5° F. and 80° F. The vegetation consists of mosses, grasses, lichens, and small shrubs, and is sufficient for cattle to maintain in good condition on the natural growth. Tussock-grass, which grows profusely, is the only plant which exceeds about 18 ins. in height. All the samples were from the neighbourhood of Grytviken Station.

Sample 2, collected 9.1.22 at about 20 feet above sea-level, consisted almost entirely of partly decomposed plant-remains. It was quite loose (*i. e.* presumably well aerated) and contained practically no mineral matter at all.

Samples 3 and 4 were taken on 9.1.22 at the top and bottom respectively of a newly-exposed surface on the slope of a hillside at a height of about 400 feet, the rest of the hill being covered with grass. They were composed of loose gritty particles with no organic matter.

Samples 5, 6, and 7 were taken on 5.5.22 at elevations of 25, 50, and 100 feet respectively above sea-level along the course of a sort of "mud river" that oozed from the hillside. The first two samples contained a little humus and plant-remains, but were mainly inorganic, while the third sample, taken at the top of the mud river, where grass was growing, appeared to be a good rather light soil with plenty of humus and some plant-fibres. All these three samples were rather richer in Protozoa than the earlier samples, but, apart from the testaceous rhizopods, Protozoa were decidedly scarce in all of them. It is however interesting to note that only one ciliate (*Cyclidium*) was found in all these soils, and this occurred in only a single culture, so was presumably very scarce.

*Elephant Island.* Sample 8.

This island is situated in Lat. 61° S. at about 650 miles from Tierra del Fuego. Its vegetation is extremely scanty, being limited to four species of mosses (all more or less stunted) and some lichens. A single sample was

taken at an elevation of about 25 feet from a shoulder which ended in a sand-spit bordering a glacier. It was a greenish-grey powder composed of sharp glassy particles, and microscopic examination failed to reveal any organic matter. The presence of penguins on the spit of land in question may account for the organic matter which is necessary for the growth of the seven or eight species of Protozoa found even in this unlikely habitat.

It is interesting to compare this result with those obtained by Penard from the material brought back from South Polar regions by the 'Charcot' and 'Nimrod' Expeditions. The French Expedition brought home samples of moss and sediment and one flask of damp earth from the localities immediately to the south of Elephant Island, viz. from the South Shetlands (Lat. 62° S.) to Charcot Land (Lat. 70° S.). From these were obtained 21 species of rhizopods, which he observes is not far short of the complete list of common bryophilous forms.

He also obtained 15 species of rhizopods in the samples of moss and sediment brought home by the British Expedition of 1907-1909 from Ross Sea (Lat. 77° to 78° S.).

#### *Tristan da Cunha. Samples 9-14.*

This group of small islands is situated roughly 2000 miles west of the Cape of Good Hope, 4000 miles north-east of Cape Horn and 1500 miles south-south-west of St. Helena. Captain Wilkins's notes mention that "The general vegetation of the island is trees (12 feet), tussock-grass, grasses, ferns, shrubs, mosses, and lichens. All classes of cereals have been grown, also most fruits suited to temperate climates, but now rats destroy most seeds and fruits. Potatoes are practically the only thing cultivated, and these need sheltering from winds." Meteorological records taken in 1908 give the rainfall as 64.8 inches and the temperature as varying between 37° and 77° F. All the samples are extraordinarily rich in Protozoa, possibly as a result of the habit of manuring frequently with sheep and cattle dung, grass, and sea-weed, a suggestion which gains some support from the fact that sample 9 contained fewer species than any of the others. The abundant moisture and absence of frosts are also no doubt favourable conditions for the development of Protozoa.

Sample 9 was taken from a newly turned over and previously uncultivated patch of soil. The adjoining land was regarded as about the average for crops.

Sample 10 was taken from a patch that had been cultivated for several years, but is regarded as the worst patch on the island.

Sample 11 was from a plot adjoining that from which 10 was taken, but is regarded as better soil, and has been well manured with sea-weed and cow dung.

Sample 12 was from a good average soil that had been under cultivation for over 20 years.

Sample 13 was from the best patch in the island. The yield of potatoes is about 25 per cent. above that of any other patch, and the potatoes are considerably larger. It has been under cultivation for over 20 years.

Sample 14 was from a fair patch that has been under cultivation for over 70 years.

In appearance all these samples were very similar, being fine crumbly soils with plenty of well-rotted organic matter mixed up with small mineral particles. Sample 14 appeared rather clayey. As might have been expected, sample 13, which came from the best agricultural plot on the island, yielded the largest number of species of Protozoa, but on the other hand, sample 10, coming from the poorest patch, was also unusually rich in Protozoa.

*Gough Island* (or *Diego Alvarez*). Samples 15-19.

Some moss brought from this island by the 'Scotia' Expedition was examined for rhizopods by Murray in 1908, and he notes that the vegetation of the island suggests a paradise for the microscopist. This remark is amply confirmed by the results of the present soil examinations. About two dozen flowering plants (including two trees) and one dozen ferns, together with mosses and lichens ("the two last in greater profusion than anywhere else I have seen"—Capt. Wilkins), compose the vegetation. The island is volcanic and situated about 250 miles south-south-east of *Tristan da Cunha*. No weather records are available, but at the time when the samples were taken (31st May) the temperature was about 51° F. and rain appeared to be abundant.

All the samples were taken within a small area at the foot of a steep ravine, and sealers who have lived at the spot claim to have grown all the common vegetables there without any special care. All the samples were very rich in humus and contained relatively little mineral matter.

*St. Helena*. Samples 20, 21.

Sample 20 was taken near *Dranas Peak* at an elevation of about 2000 ft. The rainfall (30 to 50 ins. per annum) here is higher and the vegetation more profuse than anywhere else on the island. Flax is grown in the vicinity, and all plants suited to temperate conditions grow well. The temperature ranges from 50° to 60° F. in the winter, and from 58° to 74° F. in the summer. It is rather a light sandy soil.

Sample 21 was a reddish-brown soil taken at a lower level (200 feet) near *Lot's Pillar*. This locality is not much cultivated owing to the steepness of the hillsides, but the vegetation is about the average.

Both these soils yielded all the common Protozoa found in cultivated soils.

*St. Vincent.* Samples 22-26.

This is one of the Cape Verde Islands. It is of volcanic origin and very sterile, being very subject to drought. At the time when the samples were taken (August 1922) practically no rain had fallen since the previous September.

Samples 22, 23, and 24 were taken near together from a road-cutting at an elevation of about 400 feet, at which height practically no vegetation occurs. Sample 24 was a fine soil of a type which in the moister parts of the island proves quite fertile, but naturally here appears to contain very little organic matter. In spite of this and of its dryness it yielded a few species of Protozoa.

Sample 22 was a curious fine yellow sand and 23 a very fine greyish powder taken from a depth of about 18 ins. In neither of these was any organic matter visible, and Protozoa were practically absent.

Sample 25 was a fine brick-red sand, small patches of which occur in part of the island. These patches are uncultivated and free from vegetation, and from their colour are very conspicuous. In spite of the dryness and absence of vegetation, it contained a fair number of Protozoa of all kinds, viz. flagellates, amœbæ, and ciliates.

Sample 26 was taken from the inside of the Viana Crater at an elevation of about 200 feet. The soil here is sparsely covered with vegetation (two species of *Mesembryanthemum*) and is a rather coarse sand. Sea shells occur in the crater, so presumably the sand has been blown in from the sea-shore.

*San Miguel, Azores.* Sample 27.

This is a fertile island with a vegetation very similar to that of Europe (out of 478 indigenous species, 400 are European—Ency. Brit.). Rainfall is abundant and the temperature ranges from 48°-82° F. The sample was taken at an elevation of about 800 feet on the slopes which fall to the hot springs. These slopes are unmanured, but corn is planted and is said to give an excellent yield. The soil is composed of rough, unworn, sandy particles, and contains little organic matter.

A number of Protozoa have already been recorded from these islands. Ehrenberg (6) found two species of *Diffugia* and *Trinema enchelys* in some soil from San Miguel. Archer (1) found a number of Protozoa in material collected in the hot waters of Lake Furnas by the 'Challenger' Expedition, and Barrois (2) and de Guerne (10) have also published lists of Protozoa from the same island. Most of these writers comment on the favourable conditions occurring there for the development of Protozoa and the similarity of the fauna to that of Europe, but as, with the exception of Ehrenberg, they were concerned solely with the aquatic forms, their records have little bearing on the present observations.

## NOTES ON THE ORGANISMS FOUND.

The identification of Protozoa in mixed cultures is often a matter of considerable difficulty, for when an unfamiliar organism is found, unless it presents some morphological character which puts its identification beyond doubt, there is always the possibility that it may be an abnormal form or a developmental stage of some apparently totally different organism. A name, for instance, such as *Amœba radiosa* conveys little meaning, but in order to name such forms satisfactorily it would be necessary to isolate them and follow out the whole life-history in detail—a task which, if carried out systematically, would have involved many months' additional labour, even if it had been practicable. But, as a matter of fact, cultures from isolated organisms usually die, and consequently until a more satisfactory technique for dealing with them is evolved, one has to be content with the information (ambiguous as it often is) obtained by observation of mixed cultures. These considerations apply principally to the amœbæ and flagellates. In the case of the ciliates the difficulties are of a different kind. The specific characters are usually well-defined but often difficult to observe. Thus it is impossible to observe the distribution of the appendages of a ciliate which is filled with opaque food-bodies. This must be our excuse for the number of doubtful records in the accompanying tables.

Owing to the practical ubiquity of most of the soil Protozoa, nearly all the forms found in these soils have also been found in soils from England and elsewhere, and notes on a number of them have already been published (16)

**Rhizopoda.**

*Amœba limax*.—Two common limax amœbæ occur in the soil, the active forms of which are indistinguishable. The cysts, however, are quite distinctive. The cyst of *Dimastigamœba gruberi*, the commonest soil amœba, is characterized by a perfectly smooth outer wall pierced by 5 or 6 pores. That of *Hartmanella hyalina*, on the other hand, has no pores and its outer wall is crinkled. The cysts of this type found in soil cultures, however, rarely have quite such a thick wall as that figured by Dobell and O'Connor (5); the precise identification of this form is still open to some doubt. In some cultures no cysts could be found, but most of the limax amœbæ found agreed so closely with these two forms that they most probably belonged to one or the other of them. The amœba from soil 26 was, however, considerably larger (average length when extended about  $38\mu$ ), and had an anterior contractile vacuole, so that it was probably a distinct species.

*Nebela collaris*.—A single damaged test, probably of *Nebela collaris*, was

found in soil 16. It was, however, considerably smaller than usual ( $57 \times 39 \mu$ ), and had a broad aperture ( $18 \mu$ ) without any neck.

*Microgromia*.—The specimens found were intermediate in size between the two known species *M. socialis* and *M. mucicola*. They were mostly practically spherical, with a diameter of between  $15 \mu$  and  $18 \mu$ . There was no neck, and the mouth was circular and about  $5 \mu$  across. They all appeared to be quite solitary, but, on the other hand, differed from *M. mucicola* not only in shape, but in being fairly active, the pseudopodia and contractile vacuoles being usually easily visible.

### Flagellata.

*Dimastigamæba* sp. 2, and Sp.  $\epsilon$ .—These are identical with forms of which brief descriptions have already appeared (16). They are both widely distributed soil organisms, and fuller accounts of them are in course of preparation.

The use of the name *Dimastigamæba* is somewhat ambiguous, owing to the very brief description given by Blochman to the organism for which he created the name. The name *Dimastigamæba gruberi* has been adopted for the common soil amœba under the belief that Blochman had described the flagellate stage of this amœba. Senn, however, regards *Dimastigamæba* as synonymous with *Cercobodo* Krassiltschick, and Moroff applies the name to two *Cercobodo*-like flagellates for which no non-flagellate stage has been found, and to which the present organism appears to be closely related. As a premature revision of the nomenclature would possibly simply increase the confusion, it seems better to allow the inconsistency to remain until further work makes a satisfactory revision possible.

*Spongomonas* sp.—This organism is possibly *S. uvella* Stein, but as found growing in the cultures it was always rather smaller ( $5 \mu$  to  $6 \mu$  in length), and the colonies were without any definite shape.

*Colponema* sp.—The species found differs from *C. loxodes* Stein in being rather smaller ( $9 \mu$  to  $15 \mu$  in length) and in being symmetrical, the ventral groove dividing the animal into two equal halves. An identical form has been found in a Hertfordshire soil.

*Heteromita* spp.—Several of the species of this genus (which embraces all the *Bodo*-like forms which do not possess a kinetonucleus) are very imperfectly described, and consequently their identification is uncertain. A preliminary note on the two ubiquitous soil forms *H. globosa* and *H. lens* has already been published (16). *H. oborata* is about  $10 \mu$  to  $12 \mu$  in length, with an anteriorly directed flagellum about equal to, or if anything slightly less than, the body-length, and a trailing flagellum about twice as long; they both arise at the extreme anterior end. The contractile vacuole is single and situated at the anterior end, and the nucleus is near the centre of the body. The body is roughly pear-shaped, the anterior end being bluntly pointed



and the lower surface slightly concave. Usually it has a clear glassy appearance, but at times it is filled with refringent granules. The method of swimming is very different from those of the previous species, being strong and without any spiral or vibratory movements.

*Heteromita ovata* is a larger form ( $21\ \mu \times 10\ \mu$ ), equally rounded at the two ends and somewhat compressed dorsoventrally and characterized by the possession of three contractile vacuoles, all in the anterior half of the body. The flagella arise at the anterior end of the body, and the anterior one is about twice the body-length, while the trailing one is slightly longer. The movements are slow and rather jerky. The general appearance is very like Stein's figures of this species.

*H. celer* is a smaller species (length  $3\ \mu$  to  $8\ \mu$ ), rounded behind and with the anterior end pointed and curved. The flagella arise just below the "beak," and in life the anteriorly directed one (which is only about half the body-length) is difficult to observe. The other (which is about twice the body-length) is conspicuous and trails passively. But when the organism is killed with any of the common fixatives, these positions are apparently invariably reversed, the longer flagellum being directed forwards and the shorter one laterally. The contractile vacuole is at the base of the flagella. The flagellate swims rapidly, with a screw-like movement. Apart from its movements, it is somewhat like *Bodo saltans* Ehrenb., but the nuclei were unfortunately not observed.

*Sainouron* sp.—This may simply be a variety of the common soil species *S. mikroteron*, from which it is distinguished primarily by its much larger size ( $10\ \mu$  to  $14\ \mu$ ). Ingested bacteria (rare in *S. mikroteron*) were frequently found, and the deeply-staining mass usually associated with the nucleus in the latter species (16) appears to be absent or poorly developed.

*Menoidium incurvum*.—The flagellate recorded under this name differs from the description given by Lemmermann (13) (taken presumably from Klebs) in being much narrower, the dimensions being about  $15\ \mu$  to  $18\ \mu$  in length by  $4\ \mu$  to  $6\ \mu$  in breadth. The movement also, instead of being gliding, is a rapid swimming, with a constant turning on the long axis. The appearance is very similar to that of the more slender of the two forms in Stein's fig. 53, plate xxii. (17), which he regarded as being a young stage of *Astasia proteus*.

## Ciliata.

*Balantiophorus*.—The records given here of this genus are possibly rather incomplete, as the oral membrane is often withdrawn and is consequently easily overlooked in a rapid examination, thus leading to confusion with *Enchelys*, which was often present. The species found was usually *B. minutus*, but *B. elongatus* also occurs occasionally in the soil and was present in sample 14, but as the specific differences are not always clear, no attempt has been made in the table to separate them.

## CONCLUSIONS.

The Protozoa found in the soils of these remote lands are mostly identical with those found in almost any ordinary English soil. All the forms in the table, except those marked with an asterisk, have either been found in this laboratory in soils from different parts of the world, or are included in one or other of the published lists of soil Protozoa (7, 8, 9, 18, etc.). Flagellates such as *Oicomonas termo*, *Heteromita globosa*, and *Cercomonas crassicauda*; amœbæ such as *Dimastigamœba gruberi*; and ciliates such as *Colpoda cucullus* and *C. steinii* appear to be present in practically every soil, even those which are almost barren of vegetation, while the great majority of the other species recorded have an equally wide geographical range: but at present it is impossible to say what are the factors determining their presence or absence in any particular soil. Quite possibly they occur in small numbers in most soils, and their presence or absence in cultures may be simply a matter of chance, for it is very probable that in most of the soils examined there are some species which fail to develop, either owing to the competition of more rapidly multiplying organisms, or to some other unfavourable circumstance. The three different culture media were employed in order to reduce this error as far as possible, but doubtless it still remains to some extent.

It appears, therefore, that there is a fairly well-defined and characteristic soil protozoal fauna, which (like the corresponding freshwater fauna) is practically ubiquitous.

The richest faunas were those found in soils from Tristan da Cunha and Gough Islands. The former soils had been manured with the dung of farm animals for many years, which no doubt greatly increased the bacterial activity and consequently the food-supply of the Protozoa. Some of the species may, in fact, have been introduced in the dung, for there is a close similarity between the soil forms and the coprozoic forms (19). The soils from Gough Island had also been cultivated, but unfortunately no information as to any possible past manurial treatment is available. Further observations on undoubted virgin soils would be very interesting.

The poorest soils were samples 3 and 4 from South Georgia and 22 and 23 from St. Vincent, which were all freshly exposed soil and consequently practically subsoil. The other soils from St. Vincent were also exceptionally poor.

The dryness and almost complete lack of any organic matter in these samples, in fact, makes the presence of any Protozoa at all rather surprising. Still more remarkable is the presence of species of Protozoa in some barren-looking grit from Elephant Island. Most of these species were the very common soil-forms (*Oicomonas termo*, *Heteromita globosa*, *Cercomonas crassicauda*), but there were also present *Actinomonas mirabilis* and *Biomyxa vagans*, both of which are only occasionally found in soils.

The following is a complete list of the species found, the numbers after each name indicating the samples in which it occurred :—

### **Rhizopoda nuda.**

*Dimastigamirba gruberi* (Schardinger) Alexeieff, 5, 9, 10, 11, 13, 14, 16, 21, 24, 25, 27.

*Hartmanella hyalina* (Dangeard) Alexeieff, 1, 21.

*Amœba proteus* (Pallas) Leidy, 14, 17, 18.

„ *terricola* Greef, 25, 26.

„ *diploidea* Hartmann & Nägler, 25, 26.

Unidentified spp. :—

*Limax* type, 7, 12, 15, 17, 18, 19, 20, 23, 26.

*Hyalodiscus* type, 15.

*Radiosa* type, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 25, 27.

*Terricola* type, 24, 27.

*Biomyxa vagans* Leidy, 8.

*Nuclearia simplex* Cienk., 1, 8?, 10, 11, 12, 13, 14, 16, 17, 20.

### **Rhizopoda testacea.**

*Chlamydophrys stercoræa* Cienk., 1, 15, 18, 19.

*Arcella discoides* Ehrenb., 16?, 17, 19.

*Diffugia oblonga* Ehrenb., 5.

„ *constricta* (Ehrenb.) Leidy, 5, 6, 7, 15, 16, 17, 18, 19.

„ *globulus* (Ehrenb.) Wallich, 5, 27.

„ *arcula* Leidy, 9.

„ sp., 17.

*Centropyxis aculeata*, v. *ecornis* (Ehrenb.) Leidy, 6, 7.

„ *lævigata* Penard, 5, 7, 17.

*Euglypha tuberculata* Duj., 13, 17.

„ *tuberculata*, v. *minor* (Tarán.) Hopk., 10, 21.

„ *lævis* (Ehrenb.) Perty, 13, 15, 18, 27.

„ *bryophila* Brown, 5.

„ *ciliata*, v. *glabra* Wailes, 15, 17.

„ *rotunda* Wailes, 5.

„ sp., 5, 7, 13, 14, 16, 17.

*Assulina muscorum* Greef, 2.

*Trinema lineare* Penard, 2, 7, 13, 14, 15, 16, 17, 18, 19, 21.

„ *enchelys* (Ehrenb.) Leidy, 2, 5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21.

„ *complanatum* Penard, 2, 27.

*Corythion dubium* Tarán., 16.

*Nebela collaris* (Ehrenb.) Leidy, 5, 16?.

*Sphenoderia fissirostris* Penard, 15, 16, 17, 18, 19.

*Gromia* sp., 7, 16, 17.

*Microgromia* sp., 5, 10, 13.

### **Ciliata.**

*Chaënia* sp., 13.

*Enchelys furcimen* Ehrenb., 10, 11, 12, 13, 14, 15, 16, 17, 20.

*Amphileptus* sp., 15?.

*Colpoda cucullus* Ehrenb., 9, 10, 11, 12, 13, 14, 16, 17, 19, 20, 21, 24, 25, 26.

„ *steinii* Maupas, 1, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21.

**Ciliata (cont.).**

- Balantiophorus* sp., 11, 13, 14?, 20, 25.  
*Cyclidium glaucoma* Ehrenb., 5, 15, 17, 27.  
*Chilodon cucullus* (O. F. Muell.) Ehrenb., 10, 25.  
*Uroleptus piscis* (O. F. Muell.) Ehrenb., 16, 25.  
*Gastrostyla* sp., 17, 19.  
*Gonostomum affine* (Stein) Sterki, 10, 11?, 13?, 14, 15?, 19.  
*Pleurotricha* sp., 10?, 11?, 13?.  
*Onychodromus grandis* Stein, 12.  
*Oxytricha* sp., 20.  
*Hintrio* sp., 14?, 27?.  
*Stylonychia* sp., 26.  
*Halteria grandinella* (O. F. Muell.) Duj., 20.  
*Vorticella microstoma* Ehrenb., 10, 15, 17, 18, 20.  
 Unidentified spp., 14, 15 (2 spp.), 17, 21 (2 spp.).

**Flagellata.**

- Actinomonas mirabilis* S. Kent, 8, 10, 12, 14, 15, 18, 19, 21.  
*Mastigamaba* or *Mustigella* sp., 13, 14, 15.  
*Dimastigamaba agilis* Moroff, 27.  
 „ sp. 1, 27.  
 „ sp. 2, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, 27.  
*Cercomonas crassicauda* Alexeieff, 1, 3, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21,  
 24, 25, 26, 27.  
 „ ? *oratus* Klebs, 10.  
 „ sp., 2, 3, 4.  
*Helkesimastix faecicola* Woodcock, 11, 12, 13, 14, 15, 16, 18, 19, 21.  
*Oicomonas termo* (Ehrenb.) S. Kent, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,  
 19, 20, 21, 24, 25, 26, 27.  
*Spongomonas* sp., 4, 6, 8, 10, 11, 12, 13, 15, 17?, 18, 19, 20, 21.  
*Proleptomonas faecicola* Woodcock, 13, 18.  
*Monosiga ovata* S. Kent, 11.  
*Phalansterium solitarium* Sandon, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 21, 25, 27.  
*Cephalothamnion cyclopus* Stein, 14.  
*Heteromita globosa* (Stein), 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22,  
 23, 24, 25, 26, 27.  
 „ *lens* (O. F. Muell.) Kent, 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20,  
 21, 24, 25, 27.  
 „ *obovata* (Lemm.), 10?, 18, 19, 20, 21.  
 „ *ovata* (Stein), 13.  
 „ *celer* (Klebs), 9, 10, 11, 15.  
 „ sp., 17, 26.  
 „ sp., 1.  
*Bodo saltans* Ehrenb., 15, 16, 18.  
*Phyllomitus amylophagus* Klebs, 20.  
*Colponema* sp., 10, 12.  
*Sainouiron mikroteron* Sandon, 10, 11, 12, 13, 15, 16, 17, 18, 19, 21, 24, 25, 27.  
 „ sp., 10, 11, 14.  
*Allantion tachyploon* Sandon, 9, 10, 11, 12, 13, 15, 17, 18, 19, 20, 21, 25, 27.  
 Sp. 6, 10, 11, 12, 14, 15, 17, 21.

# Flagellata (cont.).

*Tetramitus spiralis* Goodey, 1, 10, 11, 13, 14, 15, 16, 27.

„ *rostratus* Perty, 11, 14, 18?

*Tetramitus pyriformis* Klebs, 15.

*Menoidium incurvum* (Fres.) Klebs, 15?

*Petalomonas angusta* (Klebs), 10, 11, 12, 13, 14.

*Anisonema minus* Sandon, 1, 9, 11, 16, 19, 25.

*Entosiphon sulcatum* Duj., 14, 20.

*Polytoma* sp., 13.

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Some Considerations on the Host-Distribution of Parasitic Nematodes\*.

By H. A. BAYLIS, M.A., D.Sc., Department of Zoology, British Museum (Natural History). (Communicated by Dr. W. T. CALMAN, F.R.S., Sec.L.S.)

[Read 1st November, 1923.]

THE phenomenon called "specificity," or the limitation of a parasitic form to one or a few host-species, occurs in varying degrees among almost all groups of parasitic organisms. In some groups it is much more definitely manifested than in others. The Gregarines among the Protozoa and the Mallophaga (bird-lice) among the insects are usually considered as examples of very strict specificity, while among the Crustacea the Epicaridea show it to a very considerable degree.

Among the Nematodes parasitic in vertebrates there is an exceptional amount of variation in the degree of specificity shown by different genera and families, and they may be broadly divided into two categories—one with a comparatively restricted range of hosts, and one with a relatively wide range over groups of hosts which often do not seem to be at all closely related. This fact is very puzzling and seems to demand some explanation.

Before making any suggestions as regards the Nematodes in particular, the writer wishes to draw attention to some remarks by Professor Caullery, which are here translated freely from his book on Parasitism and Symbiosis, on the subject of specificity among animal parasites in general. Prof. Caullery says :—

" . . . we cannot consider the mutual specificity of parasites and their hosts as an absolute and uniform property. It is evidently one of the fundamental characteristics of parasitism ; but it is essentially relative, and manifests itself in extremely variable degrees. There are undoubtedly many cases where it is very strict, a given parasite being met with only in a single host-species. But it is nevertheless indisputable that many parasites infest, under natural conditions, several different species of hosts, and sometimes even a very considerable number of them. Specificity, then, must be considered separately in the case of each parasitic form.

" We must, further, distinguish between specificity in fact and in principle. The former is that which simple observation of natural facts shows us, the

\* A paper read before Section D of the British Association at Liverpool on Sept. 17, 1923. Several zoologists having expressed to the writer a desire that the paper should be published, it is here reproduced with a few verbal alterations only.

latter that which is the result of experiment. The limitation of a parasite to a single host in nature may depend simply on the fact that it does not meet with suitable conditions for penetrating into other hosts, and may not mean that it is incapable of developing in them. . . . Even in cases where experimental infestation of several species can be produced, it is found to succeed better with certain species than with others. We are thus led to distinguish normal from exceptional hosts. To this distinction is related the habitual restriction of parasites in nature to a particular host or to a small number of hosts. . . .

"Specificity leads also, as Roubaud has well shown, to a progressive adaptation of parasites and of their hosts, to a more and more stable equilibrium in faunas of long standing. New equilibriums and new parasitic associations are formed when a fauna is disturbed by the importation of new forms. . . .

"We are led, then, on analysing the facts, to consider the specificity of parasites as a very real thing, but of a relative kind and the result of evolution. It depends on extrinsic conditions met with in the past and in the present by the species in question, and in no way on a preordained concord [between parasite and host]. There can be no possibility of regarding parasites as forms specially devised by Providence as complementary to the life of particular hosts."

These remarks of Prof. Caullery contain a useful warning against drawing conclusions too hastily from such facts as we can observe to-day, or from experimental evidence; but the point upon which stress should be laid is that, as he says, specificity is a phenomenon of a relative kind, and one which can only be properly considered in its relation to the process of evolution.

There is, of course, a certain practical side to the question of specificity among Nematodes. It is important to know what other animals act as alternative or "reservoir" hosts for human parasites, and what wild animals for those of domestic animals. We are not immediately concerned here with this aspect of the matter, but in Tables I. and II. a selection of the facts known about it are indicated. We may now pass on rapidly to some special instances of fairly strict specificity among the Nematodes of vertebrates in general.

Certain host-species or closely-related groups of host-species have a whole series of forms peculiar to them. The elephants (which, *pace* the mammalogists, we may treat as two species only) furnish perhaps the best example of all. In the Indian and African elephants there are at least ten genera of Nematodes which are at present entirely unknown in any other host. These are indicated in Table III.\* Many of them have one or more representative

\* Prof. R. T. Leiper, F.R.S., stated during the discussion that he had seen an undescribed species of *Parabronema* from a camel, and another from a sheep.

species in each of the two hosts, but a few are represented, as far as we know at present, by one or two species in one host only. The horse tribe (Table IV.) provides a somewhat similar series, but here almost all the forms have been found in more than one host-species, the hosts including the horse, donkey, various zebras, and their hybrid offspring. There are seven genera at present confined to the horse tribe, of which one (*Cylicostomum*) is notorious for the number of its species. (The number stated in the table is quite a moderate one, which some authorities would probably increase considerably.)

The first thing that strikes one on examining such cases as these, is that the predominant factor in determining the range of the parasites must be the blood-relationship of the hosts. We may imagine that the parasites are actually older phylogenetically than their hosts, and that they have been handed down from generation to generation since they first became adapted to the conditions of life in a common host-ancestor. Unfortunately we have no information as to the geological age of Nematodes.

A certain number of other genera which have a limited host-range are shown in Table V. Some of these genera occupy a very isolated position in our present imperfect system of classification. This may be due in some cases to extreme specialization, but in many, no doubt, it is due to our lack of a sufficiently extensive knowledge of the Nematodes as a whole. The figures in brackets in the right-hand column indicate the number of known species of the genus occurring in each host or group of hosts.

Of the genera shown in the table, *Belascaris* has four fairly certain species, and its normal hosts are evidently Carnivores. According to Prof. Leiper, however, the little-known *Ascaris lonchoptera* of the elephant is a *Belascaris*. Of this species there is no recent record, although much attention has been paid lately to elephant-parasites, and it seems possible that there may have been some error about its origin. *Galoncus* is apparently a specialized branch of the Ancylostome stock, the chief hosts of which are also Carnivores. *Brachyclonus* is very closely related to *Necator*, which, as has been recently shown\*, occurs in the rhinoceros as well as in Man and other hosts, and therefore has a very wide range.

All the genera in the table show a fairly marked degree of specificity. Some of them might almost be used as criteria for deciding the relationships of the hosts, and helminthology would thus become a part of the equipment of the vertebrate systematist! In fact, in support of this idea one or two further examples may be enumerated which do not appear in the table. Thus of the genus *Crossocephalus* we know one, or possibly two, species in zebras and two in rhinoceroses, and none in any other group of animals. Consequently, had a fairly close relationship between the rhinoceros and the horse tribe not been established on the evidence of their skeletons, the

\* Baylis & Daubney, Mem. Ind. Mus., Calcutta, vii. 4 (Dec. 1922), p. 337.



discovery of the parasites might have given the student of mammals a useful clue. As a parallel may be mentioned the case of *Dictyocaulus arnfieldi*, which has been recorded not only from the horse and donkey, but also from the tapir.

*Wellcomeia* is a very curious and highly characteristic genus of the family Oxyuridæ. It has apparently, as far as our present knowledge goes, three species. One of these occurs in the North American hairy porcupines, *Erethizon* and *Acanthion*; one in the South American tree-porcupine, *Coendou*; and the third in the South African jumping-hare, *Pedetes caffer*. Now *Pedetes* does not look much like a porcupine, but its anatomical characters give very strong grounds for believing that it is fairly closely related to the porcupine family. The only difficulty about the evidence on the helminthological side is that the *Pedetes* in which the *Wellcomeia* were found had been in captivity in London at the Zoological Gardens, and it is conceivable that it was the victim of an accidental infection with material derived from another host.

How far, then, would it be correct to say that if two hosts have the same or similar Nematode parasites they must be themselves closely-related? Having due regard to all the evidence, we can only say this with very great reservations. Many genera of Nematodes range over a wide variety of hosts. In Table VI. a selection of them is indicated. These are partly genera with many species, each species having a more or less restricted range; and partly small genera whose species have an unusually wide range. To discuss them in detail is impossible, but we may consider a few of the more interesting.

*Ancylostoma* has five or six species in Carnivores, two of them also occurring in Man. A single species is recorded from squirrels.

*Necator* occurs in Man, the gorilla, and the chimpanzee, but the same species (*Necator americanus*) also occurs in the rhinoceros and has been recorded in the dog. Another species is also on record for the chimpanzee. Whether a form found in pigs in Trinidad is identical with, or distinct from, *N. americanus* appears to be still a matter of some uncertainty\*.

The genus *Strongyloides* may be mentioned here. One cannot help feeling some doubt whether all the reputed species are "good" species. The writer has seen material from a snake, the Egyptian Eryx, which it seemed impossible to distinguish morphologically from the form occurring in Man †. It may eventually prove to be the case that this species, *Strongyloides stercoralis*, the only one that is at all well known, has an extremely wide range of hosts.

*Porroecæum* has a large and still increasing number of known species, mostly in fish-eating hosts, which include mammals, birds, reptiles and

\* Gordon (Ann. Trop. Med. & Parasitol. xvii. 2 (July 1923), p. 289,) considers that the form found in pigs in South America is *N. americanus*. He finds great variation in both forms, and no constant differences between them.

† Parasitol. xv. 1 (March 1923), p. 35.

fishes. There are also, however, certain species in birds that are only semi-aquatic or purely terrestrial in their habits.

*Contracaecum* is, as far as we know, confined to fish-eating hosts.

The species of *Rictularia* seem to have very wide host-ranges. One has been recorded from a bat, a squirrel, and a fox. At the same time, the species are not well enough known at present to be identified easily. They occur mostly in mammals, but Miss Irwin-Smith has referred to *Rictularia* a species from an Australian lizard.

Of *Diocetophyme* we know only one species, which is commonly called *Eustrongylus gigas*. It has been recorded in the dog, wolf, glutton, otter, and several members of the weasel tribe; also in Man, the ox, and the horse.

Now, how are we to explain the two apparently conflicting series of facts that have been outlined? What connection have they with the evolution and inter-relationships of the parasitic Nematodes? Let us first construct an imaginary picture of the probable course of events in the evolution of the group. We must assume, first of all, that the parasitic forms are derived from free-living ancestors. This is no very unwarrantable assumption, since the free-living Nematodes are a very large and flourishing group at the present time. I think we may also assume that the ancestral parasitic form was a generalized sort of worm capable of living in a fairly wide range of vertebrate hosts. But this assumption is perhaps unnecessary, for it must be remembered that the habit of parasitism may have had its origin at a time when the available range of vertebrate hosts was not at all a wide one. The hosts themselves may have been the primitive ancestors from which all the recent groups of vertebrates have descended.

The hypothetical ancestral parasitic Nematode may perhaps have had, as some forms like *Strongyloides* and *Angiostoma* have to-day, a regularly recurring free-living phase in its life-history. After a time it would become split up into a number of forms adapted to special kinds of hosts. The hosts themselves would be evolving, and by changing their habits and diet would often be imposing new conditions upon their parasites, and all this would tend towards stricter adaptation and stricter specificity. Doubtless some of the parasites would remain more primitive than others, and would retain some of their original adaptability and lack of specificity. But others would show more and more specificity, until their habitat became very restricted because they were capable, perhaps, of living only in a few very closely-related hosts, or even in one host-species which, by reason of the course of its own evolution, had become isolated from its relatives.

Now it might, *a priori*, be expected that if a parasitic form required for its development an intermediate host, which must as a rule be swallowed by the definitive host, this would tend still further to restrict the parasite's choice of definitive hosts. Actually, however, on examining the instances

that have been quoted, it seems that the majority of the forms with a marked degree of specificity are forms which either are known to have, or from their obvious relationships to others can fairly be assumed to have, a direct development, without an intermediate host. Among the forms with wide ranges, on the other hand, we find a majority of those which are known to have, or may similarly be assumed to have, an indirect development, requiring an intermediate host. In quite a number of the genera, in fact, the intermediate host or hosts of one or more of the species have been definitely established.

Thanks very largely to the researches of Seurat, we have some knowledge of the life-histories of several genera of the Spiruroidea. Such forms as *Gongylonema*, *Physocephalus* and *Protospirura* pass their early larval stages in beetles or in cockroaches, and later larval stages of some of them have been found in a variety of vertebrate and invertebrate hosts which have preyed upon, or accidentally ingested, the insects. Such late larvæ have also been found in the case of *Physaloptera*; and although the hosts of the earliest stages are not yet known, they will doubtless prove to be insects or some other kind of invertebrates. The larva of one of the species of *Acuaria* has been found in a wood-louse, and that of another in a water-flea (*Daphnia*).

Passing to other families, larval forms which are almost certainly those of *Eustrongylides* occur encapsuled in fishes, and a similar life-history has recently been established for *Diectophyme*\*. Encapsuled larvæ of the Ascarid genera *Porroecæcum* and *Contracæcum* are extremely common also in fishes. Those species of *Porroecæcum* which live in hosts other than fish-eaters will no doubt also be found to pass their earlier stages in some terrestrial intermediate host. In the case of one of them, *Porroecæcum depressum* of birds of prey, the larva is almost certainly a form that has been known as *Ascaris incisa*, which is found encapsuled in small mammals such as shrews.

At the time when the habit of parasitism was beginning to be evolved, the eggs of some forms, when swallowed accidentally by insects, doubtless gave rise to larvæ which were able to continue their existence in the interior of the insects. If these insects were subsequently eaten by vertebrates, the parasites would be faced with the alternatives of either adapting themselves to a sudden and violent change of environment, or being destroyed. We cannot follow the steps in the process by which they have succeeded in escaping from this dilemma, but we do know something of the manner in which they survive the change now.

Maupas was the first to point out, and the fact has been verified by many observers, that the free-living larvæ of certain forms that have a direct

\* Ciurea, Compt. Rend. Soc. Biol. lxxxv. 27 (July 1921), p. 532.

development pass into their hosts at the end of the second stage of larval life, when they are enclosed in a "sheath," or, as Maupas called it, a "cyst," composed of the loosened but not yet shed cuticle of the second moult. The larvæ of some species are already in this ensheathed condition before hatching from the egg. This sheath is not lost until after the arrival of the larva in a comparatively safe position in its definitive host, and it certainly affords the delicate larva some protection both before and during the difficult period of penetration. But, even so, larvæ at this stage are easily killed by adverse conditions, such as lack of sufficient oxygen.

In the case, however, of forms with an indirect development, it is found that the larvæ are swallowed by the first host while still in the egg-shell and in the first stage of larval life, and they undergo the first moult in the tissues of the host. After this, by some process analogous to the production of plant-galls by insects, they induce the host to form round them a protective capsule of its own tissues, and inside this they undergo the second moult. The encapsuled larva, therefore, at the time of being ingested by the definitive host, has generally reached the third stage, and only the third and fourth moults have to take place within the final host. The larva thus has sufficient resistance to escape being injured when the capsule is digested. Should some animal, other than the definitive host, swallow the first host together with its encapsuled third-stage larvæ, the capsules are digested, but the larvæ usually penetrate into the walls of the alimentary canal or into the mesentery and become re-encapsuled.

The suggestion here made, then, is that, broadly speaking, forms with a direct development are more strictly limited as to their definitive hosts than are forms which have an indirect development. And this, as it seems to me, is probably because in the former the larvæ are at a younger and more tender stage of development at the time of penetration into the definitive host, this making them less tolerant of hosts for which they are not perfectly adapted. It is noticeable that, as far as our knowledge goes, the forms with an indirect development show much greater specificity for their intermediate than for their definitive hosts, and this is probably for a similar reason.

On this view, the forms that have a direct development and yet show little specificity must be supposed to have retained, physiologically at least, something of the nature of their early ancestors, and in this sense to be "primitive."

The reasons why, as a rule, forms with a direct development cannot establish themselves in many different kinds of hosts, we are not in a position to discuss fully at present. It seems, however, fairly certain that the chemistry of the contents of the alimentary canal, which must depend partly upon the nature of the food and partly upon the composition of the host's secretions, has a great deal of importance. We know that the larvæ of some

Nematodes, which undergo an extensive migration within the body of the host before settling down in its alimentary canal, can carry out their usual plan up to a certain point in a number of unwonted hosts which have been experimentally infected with them. But where they break down is when they reach the point of entering the alimentary canal for the second time. Then they usually fail to establish themselves, long enough to become mature, in any but the hosts for which they are physiologically adapted by nature. In the case of forms with an indirect development, it is evident that the swallowing of the intermediate host containing the larvæ may be either deliberate or accidental on the part of the definitive hosts, and in certain cases it seems to make little or no difference to the parasite which is the state of affairs.

I.—SOME NEMATODES COMMON (AS ADULTS) TO MAN  
AND DOMESTIC ANIMALS.

Species.	Domesticated Hosts besides Man.	Species.	Domesticated Hosts besides Man.
<i>Ascaris lumbricoides</i> ..	Pig.	<i>Toxascaris limbata</i> ....	Dog.
<i>Trichinella spiralis</i> ....	Pig.	<i>Gnathostoma spinigerum</i>	Cat, Dog.
<i>Metastrongylus apri</i> ..	Pig.	<i>Diectophyme renale</i> ..	Dog, Ox, Horse.
<i>Mecistocirrus fordii</i> ....	Pig, Ox.	<i>Ancylostoma braziliense</i>	Dog, Cat
<i>Hæmonchus contortus</i> .	Sheep, Goat, Ox.	<i>Necator americanus</i> ..	Dog (rarely).
<i>Belascaris mystax</i> ....	Cat.		

II.—SOME NEMATODES COMMON (AS ADULTS) TO DOMESTICATED  
AND WILD ANIMALS.

Species.	Hosts.	
	Domestic.	Wild.
<i>Ascaris lumbricoides</i> .....	Pig.	Swine, Apes, Squirrels.
<i>Belascaris mystax</i> .....	Cat.	Cats (Tiger, Leopard, &c.).
<i>Toxascaris leonina</i> .....	Cat.	" " "
<i>Belascaris marginata</i> .....	Dog.	Wolf, Jackal, Fox.
<i>Heterakis papillosa</i> .....	Fowl, Turkey.	Pheasants, &c.
<i>Ascaridia perspicillum</i> .....	Fowl.	" "
<i>Ascaridia columbæ</i> .....	Pigeon.	Pigeons.
<i>Subulura suctorina</i> .....	Fowl, Turkey.	Little Owl, Goatsuckers, &c.
<i>Ancylostoma braziliense</i> ....	Dog, Cat.	Carnivores (Cat and Dog tribes).
<i>Ancylostoma caninum</i> .....	" "	" " "

Table II. (*continued*).

Species.	Hosts.	
	Domestic.	Wild.
<i>Hæmonchus contortus</i> .....	Sheep, Goat, Ox.	Ruminants (Sheep, Goats, Antelopes, &c.).
<i>Trichostrongylus tenuis</i> .....	Goose, Duck, Fowl, Turkey.	Pheasant, Partridge.
<i>Physiocephalus sexalatus</i> .....	Pig.	Swine (and other hosts occasionally).
<i>Physaloptera præputialis</i> .....	Cat.	Cats (Leopard, &c.).
<i>Gnathostoma spinigerum</i> .....	Cat, Dog.	Cat and Dog tribes.
<i>Gnathostoma hispidum</i> .....	Pig.	Swine.
<i>Diectophyme renale</i> .....	Dog, Ox, Horse.	Otter, Glutton, Weasels, &c.

## III.—GENERA OF NEMATODES CONFINED TO ELEPHANTS.

Genera.	Species.		
	Indian.	African.	Total.
<i>Leiperenia</i> .....	1	1	2
<i>Parabronema</i> .....	2	1	3
<i>Quilonia</i> .....	2	5	7
<i>Pteridopharynx</i> .....	—	2	2
<i>Memphisia</i> .....	—	2	2
<i>Amira</i> .....	1	1	2
<i>Decrusia</i> .....	1	—	1
<i>Equinurbia</i> .....	1	—	1
<i>Choniangium</i> .....	1	—	1
<i>Grammocephalus</i> .....	1	1	2
<i>Bathmostomum</i> .....	1	—	1

## IV.—GENERA OF NEMATODES CONFINED TO THE HORSE TRIBE.

Genera.	No. of Species.	Genera.	No. of Species.
<i>Probstmayria</i> .....	1	<i>Cylicostomum</i> .....	31 (?)
<i>Triodontophorus</i> .....	5	<i>Cæsophagodontus</i> .....	1
<i>Gyalocephalus</i> .....	2 (?)	<i>Strongylus (sens. strict.)</i> ..	4
<i>Cylindropharynx</i> .....	3		

## V.—SOME NEMATODE GENERA WITH RESTRICTED RANGE.

Genera.	Hosts.
<b>ASCAROIDEA.</b>	
Belascaris .....	Dog, Wolf, Fox, &c. (1). Cats (1). Fennec Fox (1). Badger (1). ? Elephant (1).
Toxascaris .....	Cats (1). Dogs (1). Bears (1).
Polydelphis .....	Snakes (about 8). Chamæleons (1).
Crossophorus .....	Hyrax (2?).
Heterocheilus .....	Manatee (1).
Strongyluris ( <i>s. s.</i> ) .....	Lizards (4). Chamæleons (2).
Aspidodera .....	Opossums (2). Armadillos (2). Both groups (1).
Atractis .....	Tortoises (5). Iguanas (1).
<b>? FILARIOIDEA.</b>	
Micropleura .....	Gharial (1).
<b>STRONGYLOIDEA.</b>	
Galonus .....	Cats (2).
Ternidens .....	Man and Monkeys (1?).
Brachyclonus .....	Tapir (1).
Agriostomum .....	<i>Bos</i> , <i>Bibos</i> (1) (India and Sumatra only).
Graphidium .....	Hares and Rabbits (3).
<b>SPIRURIOIDEA.</b>	
Spiroxys .....	Freshwater Tortoises (3).
Proleptus .....	Skates (1). Dogfish (1).
Echinocephalus .....	Sting-rays (5)—one of these also recorded in a Dogfish.
Tanqua .....	Monitors ( ) Snakes (2).

## VI.—SOME NEMATODE GENERA WITH WIDE RANGE.

Genera.	Hosts.
<i>Direct development.</i>	
Subulura .....	Birds and Mammals.
Ancylostoma .....	Carnivores, Man, Pig. Squirrels (1).
Necator .....	Man, Apes, Dog, Pig, Rhinoceros.
Oesophagostomum .....	Man, Apes, Monkeys, Ruminants, Swine, Tapir, Armadillo, <i>Xerus</i> (Rodent).
Nematodirus .....	Ruminants, Hippopotamus, Rodents, Chimpanzee.
Mecistocirrus .....	Ox, Sheep, Pig, Opossum, Man.
Trichostrongylus .....	Mammals and Birds.
Trichuris .....	Mammals of various orders.
Capillaria .....	All groups of vertebrates.

Table VI. (*continued*).

Genera.	Hosts.
<i>Indirect development. (a)</i>	
Porrocaecum . . . . .	Fish-eating Mammals and Birds; marine Fishes and Turtle. Also semi-aquatic and land Birds (not fish-eaters).
Contracaecum . . . . .	Fish-eating Birds and Mammals. Fishes.
Protospirura . . . . .	Rodents and Cats.
Habronema . . . . .	Horses; Cats, &c.; Birds.
Physaloptera . . . . .	Mammals, Birds, Reptiles; Amphibia (1).
Physocephalus . . . . .	1 species in Pig, Peccary, rarely Donkey, Camel. Others in Camel (1); Sloth (2); Agouti (1).
Acuaria . . . . .	Birds (mostly birds of prey). <i>A. luteiceps</i> in both Hawks and Owls.
Camallanus . . . . .	Fishes, Freshwater Turtles, sometimes other Reptiles.
Gongylonema . . . . .	Mammals and Birds.
Rictularia . . . . .	Mammals (same species recorded in Bat, Squirrel, and Fox). 1 species (?) in a Lizard (Australia).
Eustrongylides } Hystriehis }	Fish-eating Birds.
Diectophyme . . . . .	Carnivora, Man, Ox, Horse (1 species).
(b) Probably transmitted by biting insects.	
Onchocerca . . . . .	Ruminants, Horse, Man.
Acanthocheilonema . . . . .	Carnivores (Dogs, &c.); Man; Monkeys; Jumping-shrew; Tree-porcupine.
Setaria . . . . .	Horse tribe, Ruminants.





A New Terrestrial Isopod from Zululand. By HAROLD G. JACKSON, M.Sc., Birkbeck College, University of London. (Communicated by Dr. W. T. CALMAN, F.R.S., Sec.L.S.)

(PLATES 1, 2.)

[Read 13th December, 1923.]

THE specimen described below was given to the British Museum by the Imperial Bureau of Entomology, and was collected by Mr. H. H. Curzon in Zululand. Although it is a solitary example, it is remarkable enough to justify a description. I am indebted to Dr. W. T. Calman for enabling me to give this description, and to Mr. R. B. Brook-Greaves for the exquisite and accurate portraits of a difficult subject which are reproduced on one of the plates illustrating this note.

CUBARIS SECUTOR, sp. nov. (Pls. 1 & 2.)

*Length* ca. 8.5 mm. *Breadth* ca. 5 mm.

Body oblong-oval, convex, completely contractile into a ball. Upper surface of whole body and epistome covered with setæ, forming almost a white "fur," without, however, concealing the surface.

Hind edge of each thoracic somite drawn out in the median line to a backwardly-directed spike, which is only slightly produced on the first somite, but becomes progressively larger till on the sixth and seventh somites it is a large curved tooth. In front of the median spike on each somite but the first are four large tubercles in a transverse row. The two outer tubercles of each row become progressively more sharp and drawn out in each somite; in the seventh the two median tubercles have disappeared, and only the tooth-like outer ones flank the median spike.

The flanks of each somite are raised above the coxal plates into some half-dozen longitudinal pillow-like ridges; in the last three somites the anterior ends of the ridges tend to be flattened and obliterated, leaving the posterior ends as conspicuous bosses. The seventh somite has but three of these backwardly-projecting bosses on each side.

Below these ridges a solitary whitish pimple-like excrescence bearing a single long seta stands near the hind edge of each somite on each side.

The "pronotum" (Buddé-Lund) of each somite is in the middle about one-fifth the total length of the somite. Immediately behind the "pronotum" an area of about the same length, on which the preceding somite slides, is free from setæ and furnished with scales.

The *coxal plates* are remarkably modified. On the first somite the edges are turned up to form a shield continuous in front with the greatly produced

and expanded epistome; each succeeding somite has a prominent ridge down the mid-line of the coxal plate; the backward edge of this ridge is almost vertical, while the forward (on which the preceding somite slides) has only a slight gradient (Pl. 1. figs. 1 & 3). The lateral edge of the last three somites is turned abruptly upwards to form a shelf with the edge lapped over. The postero-lateral corners of each somite are produced more or less sharply backwards.

On the under surface of every coxal plate but the seventh is a flange presenting an articulating surface into which the somite behind accurately fits (Pl. 1. fig. 2).

*Cephalon* broad and greatly exceeded in front by the expanded flattened epistome, which is continuous at each side with the raised edges of the first somite. Eyes with about 15 large ommatidia.

*Abdomen* without spines or large tubercles except on last somite ("telson"), which has two excrescences side by side at its proximal end. Pleural plates of first two somites covered by last thoracic somite. Third and fourth somites sulcate, most deeply so on each side.

"Telson" hourglass-shaped and deeply indented on each side. As broad at proximal end as whole length, and one-quarter as broad again as at distal end; posterior edge linear, not indented and not exceeding uropods. Uropods fit snugly between telson and fifth somite without leaving any gap.

*Appendages.* *Antennules* (Pl. 2. fig. 1) almost vestigial, of three segments, the distal extremity bearing 4 (?) setæ (two of which are represented only by their bases in this specimen).

*Antennæ* missing (except for the proximal segments) in this specimen.

*Right Mandible* (Pl. 2. fig. 2).—Strongly-chitinized biting tooth with three cusps; lacinia mobilis strong and tooth-like; two large setæ, setose on one side, standing in group of smaller setæ below lacinia, followed by a very large curved seta plumed on one side.

*Left Mandible* (Pl. 2. fig. 3).—Very strongly-chitinized biting tooth of crater-like formation, within which stands the very strong triconodont lacinia mobilis; three large setæ, setose on one side, standing in group of smaller setæ below lacinia, followed by a very large curved seta plumed on one side.

*Maxillulæ* (Pl. 2. fig. 4).—Lacinia exterior with ten large irregular curved teeth, setose on outer border; lacinia interior presumably lost in dissection, as no trace of it can be found.

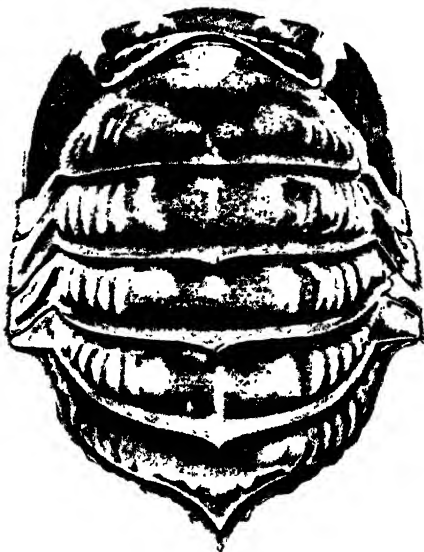
*Maxillæ* (Pl. 2. fig. 5).—Flat, with setose inner lobe; outer lobe the larger and without setæ.

*Maxillipedes* (Pl. 2. fig. 6).—Expanded and covering other mouth-parts. Inner lobe with four spines, outer terminating in curved process bearing bunch of setæ and two large setæ; on base of outer lobe on inner side a single long seta, several smaller ones scattered over base.

1.



2.



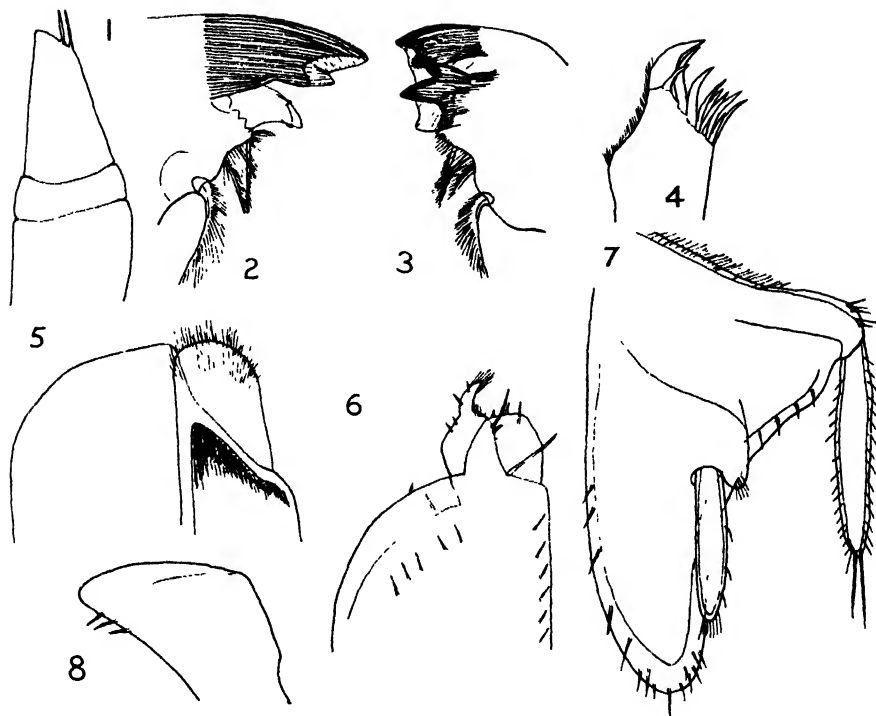
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CUBARIS SECUICR *sp nov*





H. G. J. del

Grout. photo sc.

**CUBARIS SECUTOR, sp. nov.**



*Peræopoda* have no distinctive features.

*Pleopoda* (Pl. 2. fig. 8).—First two pairs modified to form copulatory styles; remainder of typical form.

*Uropoda* (Pl. 2. fig. 7) not extending beyond telson, bluntly rounded at posterior end. Exopodite much shorter than basal plate, setose at tip; endopodite longer than exopodite, setose and with two long terminal bristles.

*Colour* (in alcohol) slate-blue flecked with grey; under surface greyish yellow.

*Locality.* Zululand, Lower Umfolosi.

*Type* in British Museum (Natural History).

*Remarks.*—There are many unusual features about this Isopod that tempt one to raise it to generic rank, in particular the form of the epistome and lateral plates of the first somite and the remarkable and unique form of the coxal plates. But the mouth-parts and other appendages are fairly typical of the “*Armadillo*” group of the Oniscidæ, and it seems safer in the present radical need for revision of these subfamilies to refer it to Brandt’s genus *Cubaris* and leave its true rank for future diagnosis. The general form is reminiscent of *Anchicubaris* \*, but the coxal plates are more modified, antennules are present, and the telson and uropods differ.

\* Collinge, Ann. Natal Mus. iv. Pt. ii. 1920, p. 484.

## EXPLANATION OF THE PLATES.

### PLATE 1.

- Fig. 1. *Cubaris secutor*, sp. nov., lateral view. The coxal plate of the third thoracic somite has been broken off.  
 2. From below; to show abdomen, ventral surface of head, and modified coxal plates on anterior thoracic somites.  
 3. Dorsal view.

### PLATE 2.

- Fig. 1. *Cubaris secutor*. Right antennule.  
 2. Right mandible.  
 3. Left mandible.  
 4. Right maxillula, lacinia exterior.  
 5. Right maxilla.  
 6. Left maxillipede.  
 7. Right uropod, dorsal view.  
 8. 1st right pleopod.





The Meaning of the Terms "Binary" and "Binominal" as applied to Biological Nomenclature. By F. A. BATHER, D.Sc., F.R.S. (Communicated by Dr. W. T. CALMAN, F.R.S., Sec.L.S.)

[Read 13th December, 1923.]

1. THE question I am permitted to discuss before a Society which should be interested in the principles of Linnean nomenclature arises out of the interpretation of the International Rules of Zoological Nomenclature, and more particularly Opinion 20 published by the International Commission on Zoological Nomenclature in 1910, and thus summarized:—

"Gronow, 1763 [Zoophylacium], is binary, though not consistently binominal. Article 25 [of the International Code] demands that an author be binary, and Article 2 [of the Code] demands that generic names be uninominal. Under these articles, Gronow's genera are to be accepted as complying with the conditions prescribed by the Code to render a name available under the Code."

This opinion provoked considerable criticisms from zoologists (see notably Poche, 1912, Arch. Naturg. lxxviii. p. 75 *et seq.*, and Lönnberg, 1914, Zool. Anz. xlv. pp. 323–326), and eventually, in 1915, Professor Apstein proposed to his fellow-commissioners that it should be reversed. It therefore became my duty as a commissioner to go into the question, and I submitted the considerations which are herewith presented. They will not be printed in the Opinion, but since the question is likely to come before the next International Congress of Zoologists, it seems advisable that they should be accessible.

2. There are two questions—a general and a special. The general question is: What is meant by 'binary nomenclature'? The special is: Shall the generic names of Gronovius 1763 be accepted?

3. The phrase 'binary nomenclature' may be interpreted by three methods. First, according to the etymology and accepted meaning of the two words that compose it. Secondly, according to its historical development and general usage by naturalists (who alone are the people concerned). Thirdly, according to its definition or any other indication of its meaning contained in the Code itself. It will at once be conceded that, whatever be the general usage, the Commission must ultimately be guided by this third criterion. None the less, the controversy cannot be understood without reference to the former criteria.

4. First, then, as to the meaning of the words in themselves. The word 'binary,' according to the Oxford, Century, and Standard Dictionaries, means consisting of two similar or related things or concepts: the word 'double' may be taken as an approximate synonym.

5. The word 'binominal' differs from binary in that it denotes specifically what the two similar things are. They are names. 'Binominal' therefore means having, or giving, a double name. 'Binomial' means having two terms, which terms are not necessarily names.

6. The word 'nomenclature' means a system of names or of naming. It does not mean a system of classification, or of anything else but names.

7. By 'a name' is meant a verbal symbol for an object or concept. It differs from a description or a diagnosis because it is essentially an arbitrary symbol, which may or may not have a meaning. All these definitions are the accepted premisses.

8. Nomenclature, then, may be explained as a method of expressing concepts by names. A System of nomenclature implies a certain orderliness of method. A system of Binary nomenclature is a regularized method of expressing concepts by double names. In other words, it is a binominal mode of expression. It is possible to speak of a 'binominal nomenclature,' but it is not elegant, for such a locution is tautological: it means 'a double name name method.' It is more elegant to speak of a 'binary nomenclature,' that is to say 'a double name method.' The expression 'binomial nomenclature' means 'a double term name method,' which comes to the same thing; but as it does not occur in the Code it needs no further discussion.

9. In accordance with these principles, we find that our Code uses the words 'binominal' and 'binary' with perfect correctness, precision, and elegance. It says (Art. 2) "*La dénomination scientifique des animaux est . . . binominale pour l'espèce*"; but it speaks (Art. 25 & 26) of "*la nomenclature binaire*."

10. In short, the natural meaning of the words 'binary nomenclature' is precisely equivalent to the meaning of the less elegant, but perhaps more explanatory, phrase 'binominal nomenclature.'

11. Let us now consider the history and general usage of the phrase 'binary nomenclature.'

12. The International Code of Botanical Nomenclature recognizes no difference between 'binaire' and 'binominale.'

13. The Code of the German Zoological Society, published in 1894 (*Verhandl. Deutsch. Zool. Gesell.* iii.) by a committee including J. Victor Carus, contains the following sections:—

S. 7. Die Anwendung des Prioritätsgesetzes beginnt mit der zehnten Ausgabe von LINNÉ's 'Systema Naturæ' (1758).

a. Unzulässig sind Art- und Gattungsnamen aus solchen Druckschriften, in welchen die binäre Nomenclatur nicht principiell zur Anwendung kommt.

b. Von Zoologen, welche der binären Nomenclatur nicht folgten, aufgestellte Namen werden nur dann zulässig, wenn sie von LINNÉ oder einem späteren Zoologen aufgenommen und charakterisiert worden sind.

S. 12. Jede Art wird mit einem Gattungs- und darauf folgenden Artnamen bezeichnet (binäre Nomenclatur).

S. 13. Der stets als ein Wort zu behandelnde Artname steht grammatisch im Abhängigkeitsverhältnisse zum Gattungsnamen.

14. The meaning of 'binäre Nomenclatur' is here made so exceedingly clear, that I find it hard to believe that Professor Carus when, in 1901, he proposed the substitution of 'binary' for 'binominal' [not 'binomial' as in par. 12 of Circular Letter 20] in the English version of Articles 25, 26 of the International Code, had any intention of introducing a different meaning.

15. It is quite unnecessary to suppose any such *arrière pensée* on the part of those who made the alteration in Art. 25 *b* as has since been attributed to them. The French version of the Code, following the words used in the rules of the French Zoological Society (1881), had the expression "*règles de la nomenclature binaire*." The German version, following the rules quoted above, had "*Grundsätzen der binären Nomenklatur*." The English version, following common English usage, had "the principles of binominal nomenclature." Therefore the subcommittee appointed to edit the Code and to remove such verbal inconsistencies, naturally substituted 'binary' for 'binominal.' This alteration, whatever were the reasons for it, could not change the sense of the Code, for in cases of doubt that has to be interpreted from the French version, and in that there was no such change.

16. Let us now consider the French version and its history. This can be found in Professor R. Blanchard's '*Deuxième Rapport sur la nomenclature etc.*' (1892. Also 1889).

17. In Section 2 "*la nomenclature binaire*" is plainly used to denote the binominal mode of expression: and a proof of this is the rule that the name of a variety is to conform to the rules governing "*la nomenclature binaire*."

18. Article XI *b* corresponds to 25 *b* of the International Code. It runs: "*Que l'auteur ait effectivement entendu appliquer les règles de la nomenclature binaire*." Professor Blanchard elucidates this as "*d'après la méthode binaire et binominale*," that is to say, the binary method of classification and the binominal method of expression.

19. It is useless to go on piling up evidence that naturalists in general, and the most prominent among nomenclatorists in particular, have used the phrase 'binary nomenclature' for the binominal method of denoting species. It is more interesting to enquire how anyone ever came to attribute to it any other meaning.

20. The explanation seems to me to lie in the very next section of Professor Blanchard's '*Rapport*' (S. 70), in which he enquires "*Qui est l'inventeur de la nomenclature binaire?*" The Code would assign this honour to Linnæus, but Professor Blanchard, after a long discussion of Belon and others, concludes (S. 73): "*C'est à Tournefort que revient sans conteste la gloire d'avoir fondé la nomenclature binaire*."

21. Reference to Tournefort's remarkably lucid introduction or 'Isagoge' to his 'Institutiones' makes it quite clear what Tournefort did. In the first place he used a method of binary classification *per genus et differentiam* (see p. 63), which in itself was an adaptation of the old logical system, and had previously been used in natural history. Secondly, Tournefort insisted that the appellation of the genus should be a name pure and simple (as defined in par. 7 above), and he ridiculed constant reference to its etymology. It is this which seems to be his chief step in advance. Thirdly, he made an attempt to limit the length of the specific differentia, sarcastically commenting on some verbose examples. This specific differentia is not a name in the same sense as the generic appellation is a name; it is rather "quædam veluti definitio"—intended to remind the reader of the nature of the plant. It is not a description, but corresponds rather to the brief 'diagnosis' of Linnæus. It should be short, no doubt, and in order to keep it so, new genera "audacter constituenda esse" "eo quod novis generibus statutis, novum tantummodo nomen introducatur, singularum specierum appellationes contrahens." Which means "The more you split your genera, the shorter your specific diagnoses."

22. Such is the method of Tournefort, obviously something quite different from the method of 'Systema Naturæ' X. The further step taken by Linnæus was the inevitable next step, namely the substitution of a *nomen triviale* for the specific differentia, this *nomen triviale* being a true name. Thus the appellation of the species, instead of being an assemblage of words "quarum prima vox genus plantæ, ceteræ differentiam expriment," became a *nomen specificum*, composed of the *nomen genericum* followed by the *nomen triviale*. Thus the reason given by Tournefort for the multiplication of genera ceased to exist, for, however many species a genus might contain, the name of each species remained composed of two words only. This shows clearly that the method of Linnæus was essentially different from that of Tournefort and constituted a real advance.

23. I am not discussing whose is the greater 'glory,' but I am attempting to show how it is maintained that, if Tournefort was the founder of 'la nomenclature binaire,' then the method of Linnæus, the method adopted by the zoologists and botanists of the last hundred and fifty years, has no peculiar right to that appellation.

24. If confirmation of this opinion were needed, it would only be necessary to pass to the other Pre-Linnean authors whom Professor Blanchard adduces as users of Tournefort's 'nomenclature binaire.' I will take only one, C. N. Lang, whose book 'Methodus Testacea Marina etc.' (1722) is at my hand. I open this at Section III., *Cornua Ammonis*. One may perhaps concede that phrase to be a single name in the strict Tournefortian sense. But it is the name of a group. Then comes S. I. *Cornua Ammonis unita*, which phrase combines two concepts and is therefore binary. Next is Genus 1,

*Cornua Ammonis unita proportionata*, a tertiary phrase. That genus contains two Species, of which the first is called *Cornu Ammonis unitum et proportionatum leve*, a phrase combining four concepts and therefore quaternary. The binary idea of genus and species is there, but the mode of expression is not binary. If this is what Professor Blanchard means by 'nomenclature binaire,' then again he cannot apply the same phrase to the method of Linnæus, 1758.

25. What the formulators of Opinion 20 and similar opinions may have understood by 'binary nomenclature,' I do not know. I know they do *not* mean, as everyone else does, the method of Linnæus, 1758; and I suppose them to mean either a mere recognition of such things as genus and species, or an attempt to distinguish the genus by a definite name rather than by a descriptive phrase. But what they actually mean they have never troubled to explain.

26. But what they meant then or what they mean now is of small importance compared with the meaning of the phrase as ascertained from our third and final source, namely the Code itself.

The phrase occurs in Art. 25 *b* and in Art. 26.

Art. 25.—The valid name of a genus or species can be only that name under which it was first designated in the condition :

*b.* That the author has applied the principles of binary nomenclature.

Art. 26.—The tenth edition of Linné's *Systema nature*, 1758, is the work which inaugurated the consistent general application of the binary nomenclature in zoology. The date 1758, therefore, is accepted as the starting point of zoological nomenclature and of the Law of Priority.

27. Art. 25 *b* throws no light whatever on its meaning. It may, perhaps, be pointed out that in the English version there is no definite article, whereas in Art. 26 the words are 'the binary nomenclature'; and it might conceivably be argued therefrom that the phrase in Art. 25 *b* was not necessarily restricted to precisely the same form of binary nomenclature as that indicated in Art. 26. Such an argument would not hold, because in both the German and the French version the definite article is duly inserted. In the old form of the English version there was no necessity for the definite article, but when the change previously noted was made it would perhaps have been better had the article been inserted.

28. To find out what 'la nomenclature binaire' means in Art. 25 *b*, we must turn to Art. 26, and there we read that it is the method of nomenclature the general application of which was inaugurated by Linné's '*Systema Naturæ*' X (1758). The phrasing of this Article as it exists to-day dates from the same period as the introduction of the word 'binary' into Art. 25 *b* English version. There can therefore be no excuse for supposing that the phrase was ever intended to differ in meaning in the two Articles.

29. What the phrase must mean in Art. 26 is perfectly well known to every systematic biologist, and has moreover been clearly set forth above (par. 22). That meaning is congruous with the etymology, with the dictionaries, with the history, and with general usage. If it was not more specifically defined in the Code, that can only be because the meaning was so well known and universally accepted. The only exceptions are Professor Blanchard's ascription of 'la nomenclature binaire' to Tournefort and the assumptions at the base of Opinion 20.

30. To turn now to the question: Shall the genera of Gronow, 1763, be accepted? The statement in the Discussion of Opinion 20 that "Gronow's specific designations are polynominal and diagnostic" is correct if for 'polynominal' we read 'multiverbal,' which no doubt is what was intended. Some of Gronow's generic names are uninominal, and some are not; but I do not wish to confuse the issue, so I will lay no stress on a few deviations from the binary method. It is enough to say that the 'Zoophylacium,' 1763, shows no difference in method from the 'Museum Ichthyologicum,' 1754.

31. The Discussion, however, proceeds to say: "It is clear that Gronow's nomenclature is binary, that is, he names two units or things, genera and species." I decline to accept this statement. It is true that Gronow classifies his material under the double concept of genera and species, and it may be conceded that he has a distinct name for most of his genera. But his "specific designations are diagnostic," that is to say they correspond to the specific differentia of Tournefort, not to the *nomen triviale* of Linnæus or to any other thing to which the term 'name' can properly be applied.

32. In particular the mode of expression adopted by Gronow does not correspond, either in principle or in practice, with the method which our Code denotes as 'la nomenclature binaire.'

33. Opinion 20 is therefore in contradiction to the Code, and is, in my opinion, *ultra vires*.

34. What then is to be done? If the conclusions at which I have arrived are correct, it is plain either that Opinion 20 (and those proceeding from the same interpretation of Art. 25 *b*) must be cancelled, as Prof. Apstein proposes, or that the Code must be altered to bring it into conformity with the Opinions. Such alteration would affect Art. 26, and would substitute some other definition of the phrase 'la nomenclature binaire.'

35. If the majority of 11 to 1 by which Opinion 20 was carried really represented the views of the majority of systematic zoologists, it would be necessary to adopt the latter alternative and to alter the Code. But from the subsequent discussions within the Commission, from the criticisms that have been published, and from conversation or correspondence with many colleagues, I have formed the opinion that the majority of systematic zoologists would welcome the former alternative, namely the cancellation of Opinion 20 (and similar ones).

36. In an ordinary case I should attach great weight to the plea that a matter so definitely settled by the Commission should not be re-opened, at any rate after so short an interval. But I venture to hope that the arguments herein brought forward may place the matter in a new light, and that my colleagues of the Commission may now agree that Opinion 20 is and always was opposed to the Code.

37. But, even if this were agreed to, I should consider that greater precision was required in the Code. It is an astonishing fact that the composition of the *nomen specificum* is nowhere defined. It is also remarkable that no clear indication of the system of nomenclature intended should be given before Art. 26; and even that indication does not seem to have been clear to some people. When I consider this Code critically my admiration for Linné's 'Philosophia Botanica' is increased. It would be well if some of Linné's canons were incorporated in the Code.

38. The system of interpreting an ambiguous code by means of a series of Opinions—in other words, the piling up of a confused mass of what lawyers call 'case-law'—is a system contrary to the spirit of science.

*Postscript.* 29 February, 1924.

Wishing to get rid of Gronow (1767) and of certain other works in the same category, and desirous of avoiding the delay and inconclusive discussion consequent on the proposal to rescind Opinion 20, Commissioner D. S. Jordan has proposed "Under suspension of the rules" to eliminate those works "from consideration as respects their systematic names." As practical men the British Commissioners are voting for Professor Jordan's proposal: but, since they all maintain that Opinion 20 is itself in contradiction to the rules, they accompany their vote with a reservation to that effect. I have phrased my own reservation thus—"That the proposed Opinion read as follows:—Under suspension of the rules in any case where such suspensions may be considered necessary according to the interpretation now or hereafter adopted by the Commission, the following works or papers are declared eliminated &c."

F. A. B.





On the Polychaeta collected by H.M.S. 'Alert,' 1881-1882. Families Polynoidae, Sigalionidae, and Eunicidae. By C. C. A. MONRO, F.L.S.

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(With 24 Text-figures.)

[Read 5th June, 1924.]

#### INTRODUCTORY REMARKS.

IN 1881 a volume entitled 'Report on the Zoological Collections made in the Indo-Pacific Ocean during the Voyage of H.M.S. "Alert," 1881-2' was published by the British Museum. This volume contains a systematic account of the greater part of the material presented by the Admiralty to the British Museum, but no report upon the Polychaeta, a substantial collection of which was obtained by Dr. R. W. Coppinger off the coast of Queensland and in the China Sea, besides a few collected in the Magellan region. The present paper is an account of three families belonging to this collection which has remained untouched in the possession of the British Museum for over forty years. I have in one or two cases included in my descriptions specimens in the possession of the British Museum other than those belonging to the 'Alert' collection.

I have followed Fauvel, McIntosh, and others in retaining the name *Eunice* as against *Leodice*, although the latter has priority.

#### Family POLYNOID.E.

##### THORMORA JUKESI, Baird.

*Thormora Jukesi*, Baird, 1865, p. 199.

*Polynoe trissochaetus*, Grube, 1869, p. 485.

*Lepidonotus trissochaetus*, Grube, 1878, p. 25, Taf. 2, fig. 4.

*L. trissochaetus*, Willey, 1905, p. 249.

*L. trissochaetus*, Potts, 1910, p. 331.

*Thormora trissochaeta*, Horst, 1917, p. 75.

*Lepidonotus (Thormora) Jukesi* (Baird), Seidler, 1924, p. 88.

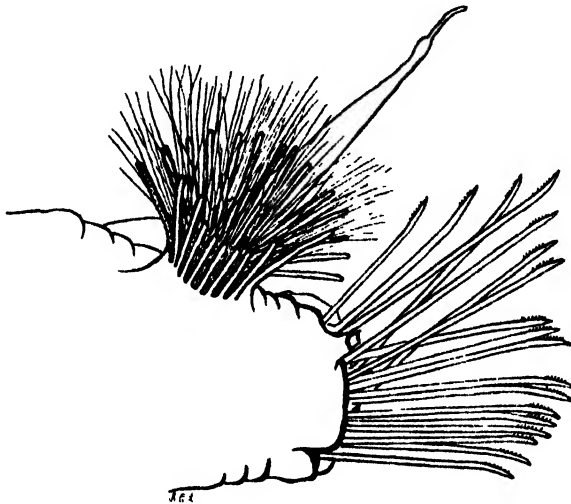
*Occurrence* :—"Port Moller, Queensland. Beach and coral reef." "East Australia."

*Description* :—Two complete specimens and one anterior fragment from "East Australia," and one specimen in two pieces from Port Moller. The largest complete specimen measures 17 mm. × 5 mm., including the feet.

At first sight the specimens labelled from E. Australia appear to be very different from that of Port Moller. The former are light yellow in colour, and have no colour-markings either on the elytra or on the dorsum.

Moreover, the notopodial chætæ are in a state of retraction, and the stout spinous chætæ form a close fence round the slender capillaries, almost entirely concealing them in the anterior segments. The specimen from Port Mollo is light grey in colour, and its dorsum and elytra are generously marked with black. The notopodial chætæ are protruded, and the lobe from which they arise projects markedly from the dorsum of the foot. The stout spinous chætæ are spread out in a radiating fashion around the very prominent central capillary chætæ (fig. 1).

FIG. 1.

*Thormora Jukesi*, Baird.

Anterior foot, showing the notopodial chætæ expanded.  $\times 24$ .

*Remarks* :—Horst (*loc. cit.*) objects to Augener (1913, p. 107) identifying the *Polynoe trissochotus* of Grube with the *Thormora Jukesi* of Baird on the ground that the elytra in Grube's type are described as "marginæ lævi," while Baird's type is mentioned as having elytra which are "ciliated on the external margin." I have examined Baird's type-specimen, and I am unable to find any trace of marginal ciliation on the elytra. I therefore feel justified in following Augener in uniting these two species.

Willey (*loc. cit.*) suggests that this species has been separated from the *Lepidonotus indicus* of Kinberg, only upon the differences in the state of retraction of the notopodial chætæ. Kinberg's (1857, p. 15, pl. 4, fig. 19) figures, however, show that in his species the tentacles and the dorsal cirri are ciliated, while in *T. Jukesi* they are smooth, also that in his species the neuropodial chætæ are bidentate, while in Baird's they are unidentate.

**HERMENIA ACANTHOLEPIS (Grube).**

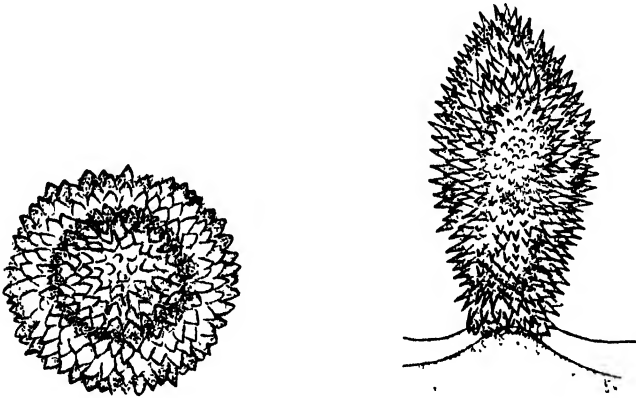
*Polynoe (Lepidonotus) acantholepis*, Grube, 1878, p. 24, pl. 2. fig. 1.

*Lepidonotus acantholepis*, Horst, 1917, p. 67.

*Occurrence* :—"Goto Island, Japan."

*Description* :—Two specimens, one 27 mm. long by 7 mm. broad, the other 18 mm. long by 5 mm. broad, excluding the feet. Colour a pale iridescent grey, with a wide longitudinal band of olive-green down the mid-dorsal line. The epidermis is very much wrinkled and folded, and the dorsal surface is crossed by narrow transverse furrows throughout its length. There is no trace of eyes, but this may be due to the long sojourn in spirit. The median tentacle is more than twice as long as the laterals. These and all the dorsal cirri have a subterminal swelling followed by a fine flagelliform process.

FIGS. 2 & 3.



*Hermenia acantholepis* (Grube).

Fig. 2. Round tubercle of elytron.  
× 150.

Fig. 3. Ovoid tubercle from same elytron.  
× 90.

The first three pairs of elytra are of moderate size and almost cover the dorsum; the remainder are much reduced, their longest diameter being about equal to the distance from the base of the pro-torium to the apex of the ceratophore of the median tentacle. All the elytra are covered with tubercles, which also overlap the edge on all sides except for a short space on the inner anterior border of the 2nd and 3rd elytra, where they are covered by the overlapping edge of those in front, and the tubercles are much reduced. The tubercles are of two kinds: the centrally placed ones are conical, with a wide rim or border, the whole being composed of small plates surmounted by conical spines (fig. 2); the others, on the edge of the elytra, are ovoid, with their surface composed of minute circular plates with more slender spines (fig. 3).

The foot consists of a rounded, much wrinkled lobe, from the end of which projects a fan of strong golden-brown neuropodial chaetæ with a tridentate apex, consisting of a curved terminal tooth facing two large transverse teeth. On the anterodorsal surface of the lobe is a minute bundle of 4 to 5 very fine tapering bipectinate chaetæ, which represent the abortive notopodial bundle. The dorsal cirrus of the 3rd foot is longer, and arises at a point further from the body than the remainder, which are set very far back on the feet. The ventral cirri, except for those of the 2nd segment, which are long and shaped like the dorsal cirri, are mere papillæ on the ventral surface of the foot. There are two anal cirri, and the nephridial papillæ are most conspicuous.

My specimens agree in all essentials with Grube's description and figures. The neuropodial chaetæ, as Michaelsen showed, are tridentate and not bidentate in this species. Grube's figure does not show the sudden decrease in size of the elytra after the first 3 pairs, which characterises my specimens; but we are dealing with an organ in the process of reduction, and variations in the size of that organ do not warrant the establishment of a new species.

*Remarks* :—Seidler (1924, p. 94) correctly refers this species to *Hermenia*. The reduction of the elytra is not carried so far as in *H. verruculosa*, and although there are marked differences, such as the presence of two transverse teeth on the shaft of the ventral chaetæ of this species, between *H. verruculosa* and *H. acantholepis*, I am inclined to regard the latter as showing a stage in the reduction of the elytra intermediate between the former and a typical *Lepidonotus*. Moreover, the reduction of the elytra characteristic of this genus is accompanied by a modification of the integument. In *H. acantholepis* it is very much furrowed and wrinkled, and in *H. verruculosa* it is covered with warty tubercles. Seidler (1924, p. 94) redefines *Hermenia* to include *H. acantholepis*. He includes in his generic definition the presence of a paired tooth on the shaft of the neuropodial chaetæ. I am unable, however, to find any trace of the 2nd tooth, which he asserts to be present in a rudimentary condition in *H. verruculosa*.

#### HERMENIA VERRUCULOSA, Grube.

*Occurrence* :—"Darros Island, the Amirantes."

*Remarks* :—One specimen 33 mm. long by 7 mm. broad, including the feet. I believe this to be the first record of this species outside the West Indies, where it is plentiful, and I had some hesitation in extending the range of this curious form from the West Indies to the Indian Ocean, especially as there is no record of any intermediate stages in its distribution, but my specimen corresponds so closely in detail to Treadwell's (1911, p. 9, figs. 23-26) description and figures that I have no choice.

Curiously enough, both palps are missing in my specimen, as they were in Grube's type. Grube (1856, p. 44) accordingly writes "*lateralium nulla*"

in his generic definition. Treadwell, with more material at his disposal, corrects this error.

### HALOSYDNA STRIATA (Kinberg).

*Lepidonotus striatus*, Kinberg, 1855, p. 384; 1857, p. 14.

*Polynoe fulvovittata*, Grube, 1878, p. 33, pl. 3. fig. 1.

*P. platycirrus*, McIntosh, 1895, p. 111, pl. 3. fig. 4 etc.

*Halosydna fulvovittata*, Marenzeller, 1902, p. 7.

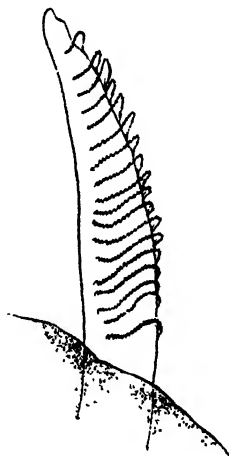
*Polynoe platycirrus*, Potts, 1910, p. 336, pl. 18. fig. 8 etc.

*Halosydna fulvovittata*, Horst, 1917, p. 80.

*Hyperhalosydna striata*, Augener, 1922, p. 6; Seidler, 1924, p. 136.

*Occurrence* :—"Port Mollo, beach and coral reef." "Port Denison, sand and shell, 4 fms." "Thursday Island, 4-7 fms., sand."

FIG. 4.



*Halosydna striata* (Kinberg).

Dorsal chaeta.  $\times 475$ .

*Remarks* :—One complete specimen 26 mm. long by 6 mm. broad from Port Mollo, two fragmentary ones from Port Denison, and one specimen 30 mm. long by 5 mm. wide, including feet, from Thursday Island.

The colour of the Port Mollo specimen is pale yellow with narrow transverse bands of grey across the dorsum. The longitudinal stripes on the elytra are also a bluish grey. In the anterior half of the body the pigment is more generally distributed over the elytra, and not so much confined to uniform stripes as in the posterior half, although the general effect of continuous lines from head to tail is not impaired. There is a single small keel near the posterior edge of the elytra, which number 21 pairs in all. They are not represented on the eight most posterior segments of the body, which are consequently uncovered.

Three or four dorsal chætæ similar to the smaller type figured by McIntosh (1885, pl. 9 A, fig. 1) are present. The tothing in these chætæ is more pronounced than that in McIntosh's figure, the apex being beset with denticulated rows (fig. 4).

The Port Denison specimens show certain colour-variations. The stripes on the elytra are partly dark grey and partly orange. In the more anterior elytra the dark grey predominates, but posteriorly there is more orange. The elytra have each a black spot over the point of attachment and are without keels. As Horst (1917, p. 81) points out, there is much divergence in the observations as to the relative length of palps and tentacles in this species. In my specimens the palps are longer than the median tentacle. The dorsal tentacular cirrus is approximately the same length as the median tentacle. Most of the flattened dorsal cirri have been lost.

The curious tubercles on the anterior border of the elytra to which Marenzeller (1902, p. 7) and Horst (1917, p. 81) call attention differ slightly in the specimens from the two localities. In the Port Molle specimen they are almost circular, and the slit or canal is not always to be seen. In the Port Denison specimens, however, they are oval, and the canal is very easily visible.

The Thursday Island specimen shows some further colour-variation, the striping of the elytra being composed of shades of chestnut-brown. There are also two small keels on the elytra, and the tubercles resemble those of the Port Denison specimen.

Augener's new genus *Hyperhalosydna*, established for this species, appears insufficiently differentiated from *Halosydna*.

Seidler (1924, p. 137) maintains that in this species there are no dorsal bristles, but only an aciculum, and he includes this character in his redefinition of Augener's *Hyperhalosydna*. This is an error. Dorsal bristles have been described by McIntosh and Horst, and are here figured (fig. 4). The specimens examined by Potts and Grube, however, apparently did not show any.

#### *HARMOTHOE TERMINOCULATA*, sp. n.

*Occurrence* :—"Port Jackson, 0-5 fms."

*Description* :—Five specimens which I am unable to assign to any known species, the largest being 19 mm. long by 7 mm. broad, including the feet. The species is readily distinguishable by the position of the anterior pair of eyes, which are situated very far forward on the ventro-lateral surface of the apexes of the frontal lobes (fig. 5) and by the long, slender, marginal papillæ, which grow not only upon the posterior and external edge of the elytra, but also on the adjacent area of the elytron itself (fig. 6). The elytra are covered with small tubercles, except for a little space behind the anterior border.

The posterior pair of eyes are large, dorsal, and situated just in front of the nuchal fold. The median tentacle, which, like the other tentacles and the dorsal cirri, is ciliated, is about three times as long as the laterals.

Both notopodium and neuropodium terminate in a long digitiform process containing the aciculum. The neuropodial chaetae are delicately bidentate, with a long spine-free apex. The ventral cirrus is short and beset with minute papillae.

*Remarks*:—This species resembles *Harmothoe atra*, Horst, and *Harmothoe areolata*, Grube, in the position of the anterior eyes, but differs from both these species in the character of its elytra.

FIG. 5.

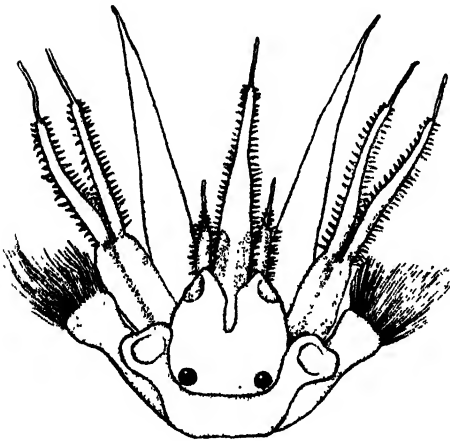
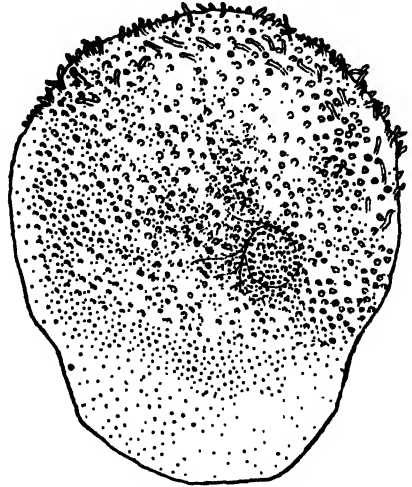
Head.  $\times 18$ .

FIG. 6.

Anterior elytron.  $\times 21$ .

*Harmothoe terminoculata*, sp. n.

#### LEPIDASTHENIELLA, gen. nov.

*Generic diagnosis*:—Body long, vermiform, and strongly pigmented. Insertion of lateral tentacles terminal. Elytra numerous, up to 90 pairs, which show gradual reduction in size posteriorly and occur on the 2nd, 4th, 5th, 7th, and on every alternate segment to the end of the body.

This genus agrees with *Lepidasthenia* in all characters except in the arrangement of the elytra, which occur on alternate segments instead of on every third segment after the 23rd, as is the case in the latter genus. For a discussion of this point, see Fauvel (1917, p. 185).

Genotype, *Polynoe comma*, Thomson, 1902, p. 241.



*LEPIDASTHENIELLA PHILLIPPENSIS*, sp. n.*Lepidasthenia comma*, Fauvel, 1917, p. 182.Non *Polynoe comma*, Thomson (*loc. cit.*).Nec *Lepidasthenia comma*, Benham, 1909, p. 237.Nec *L. comma*, Ehlers, 1907, p. 6.*Occurrence* :—"Port Phillip Head, South Australia."

*Description* :—Two complete specimens and one fragment. The larger of the complete specimens consists of 84 segments, and is 112 mm. long by 7 mm. broad, including the feet; the smaller measures 97 mm. in length. The width is slightly greater anteriorly than posteriorly. There is very little to be added to Prof. Fauvel's excellent description and figures.

The coloration appears to be very variable within the species. The largest of my specimens is much more deeply pigmented than the others. In the anterior segments the dorsum is a deep black, relieved by small patches of yellow where the dark pigmentation is interrupted. There are also black patches on the upper surface of the foot. A reddish-brown mid-dorsal band of pigment, which in the more posterior part of the body runs plainly down the middle of the back, is scarcely discernible anteriorly. There is a tendency for the cirriferous segments to be less strongly pigmented than the elytriferous, which tendency is more marked posteriorly, so that in the posterior half of the body there is an alternation of black with yellow segments.

On the ventral surface in the largest specimen there are two black patches on every segment and also a black patch at the base of every foot near the nephridial papilla. In the other two these ventral markings are only faintly discernible. In all the specimens the prostomium is liberally spotted with black.

The median tentacle is lacking as it was in Fauvel's specimen. The dorsal cirri of the 3rd, 6th, and 8th segments are of considerable length, projecting well beyond the feet. They diminish in size posteriorly until at about the 30th segment they just reach the end of the foot. The ventral cirri are very short except for that of the 2nd foot, which is of moderate length.

The first few elytra, which are colourless except at the area of attachment, just fall short of entirely covering the dorsum. They decrease, however, very rapidly in size until in the posterior half of the body they only just cap the elytriferous. In my specimens they appear to be more reduced than in that of Fauvel, and to approach the condition found in *Lepidasthenia microlepis*, Potts, 1910, p. 343.

Like Fauvel, I was unable to observe any trace of dorsal chætæ.

*Remarks* :—This species is quite distinct from *Lepidastheniella comma* (Thomson) figured here, two specimens of which from New Zealand have been presented to the British Museum by Prof. Benham. In *L. comma* the

reduction of the elytra in the posterior region is slight, only a small portion of the dorsum being left uncovered. Moreover, there is a considerable

FIG. 7.

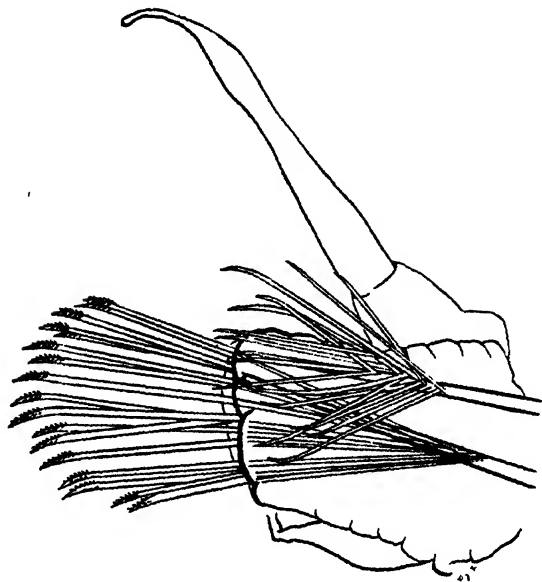
Anterior foot.  $\times 40$ .

FIG. 8.

Notopodial chaeta.  $\times 240$ .

FIG. 9.

Neuropodial chaeta.  $\times 280$ .

*Lepidastheniella comma* (Thomson).

dorsal bundle of upwardly-pointing slender chaetae with spiral whorls of delicate teeth (figs. 7 and 8), and, on the neuropodial chaetae (fig. 9), there is no trace of the crest which is so characteristic of *L. phillippensis*.

Finally, in *L. comma* I could discover no chaetæ of the type figured by Fauvel in his text-figure "d" which occur in the superior fascicle of the neuropodium of the anterior segments of *L. phillippensis*.

Seidler (1924, p. 152) having adopted Webster's *Lepidametria* to comprise all the species of *Lepidasthenia* in which the arrangement of the elytra is irregular, includes among them *Polynoe comma*, Thomson. This is unsatisfactory, because in this species the elytra are situated on every alternate segment with complete regularity. Moreover, in his generic definition of *Lepidametria* he gives as a character the presence of dorsal bristles in the anterior region of the body. In *L. comma* the dorsal bristles are not confined to the anterior region. In the posterior segments they are still present though much reduced.

#### IPHIONE MURICATA, Savigny.

*Occurrence*:—"Thursday Island, 4-7 fms., sand." "Prince of Wales Channel, 7 fms., sand." "Port Molle, beach and coral reef." "Clairemont and Bird Islands." "Gulf of Siam."

*Remarks*:—Twelve specimens in all. They correspond closely and in detail with Gravier's (1901, p. 226, pl. 9, figs. 129 & 130) description and figures. The larger specimens are about 17 mm. long by 14 mm. broad, excluding feet.

In the specimen from the Prince of Wales Channel the nuchal fold extends unusually far over the prostomium so as completely to conceal the eyes. The small tubercle between the eyes is more developed in some than in others; but this appears to be an individual variation, and I am unable to correlate it with a difference in locality. The rows of teeth on the ventral chaetæ are more pronounced than those shown in Gravier's text-figure 239.

#### Family SIGALIONIDÆ.

##### LEANIRA QUATREFAGESI, Kinberg.

*Leanira Quatrefagesi*, Kinberg, 1855, p. 388; 1857, Taf. 9, fig. 42.

*L. Quatrefagesi*, Ehlers, 1901, p. 59, Taf. 5, fig. 8.

*Occurrence*:—"Cockle Cove, Straits of Magellan, 2-32 fms., bottom mud."

*Remarks*:—Six specimens, one complete and five fragmentary. The complete specimen is about 80 mm. long by 4 mm. broad anteriorly and 3 mm. posteriorly, excluding feet.

Kinberg's figure (42 B) of the head is misleading in one respect. It gives the impression that the chaetæ of the 1st segment are situated dorsally to the dorsal tentacular cirrus, which is not the case. Actually they are situated internally to the dorsal cirrus, which lies above them but

further removed from the median line. Ehlers, on the other hand, misinterprets the homologies of the organs connected with the head, and speaks of the lateral tentacle which is fused with the first foot as a papilla on the dorsal surface of the base of the foot. Moreover, he seems to regard the exceedingly long palps as the ventral cirri of the first foot. Actually, as Kinberg's figure shows, there is a median tentacle which is fused with the prostomium for about half its length, the two minute lateral tentacles which arise from the dorsal surface of the first foot, a long dorsal cirrus about one fourth the length of the palps, a small delicate ventral cirrus, and the enormous palps which, when laid along the back, reach to the 26th chaetiger. The cirriform gills appear as small papillæ on about the 20th segment, and reach their full size ten segments further back.

The dorsal chaetæ are of two kinds—the one very fine, long, minutely hispid capillaries; the other stouter and with spiral whorls of small teeth. In my specimens the toothing is more pronounced than that in Kinberg's figure 42 G. In the posterior half of the body the blade of the compound chaetæ is much shorter than in the anterior segments, and the canaliculation is sometimes very difficult to detect. In the anterior segments they are as figured by Kinberg. Ehlers' figure of a foot (Taf. 5. fig. 8) would lead one to suppose that the canaliculation is continued below the joint of the compound chaetæ on to the shaft. This is, of course, not the case. With Ehlers I am unable to observe any ctenidia.

**PSAMMOLYCE ANTIPODA, Schmarda.**

*Occurrence* :—"Holothuria bank, 39 fms."

*Remarks* :—Three fragments, all lacking the head. Examination of the feet and elytra, which correspond in detail with Fauvel's (1917, p. 186, pl. 4. figs. 12 & 13, text-fig. x.) description and figures, leaves no doubt as to the identification of these fragments. I can add nothing to Fauvel's careful comparative study of this species.

**SIGALION OVIGERUM, sp. n.**

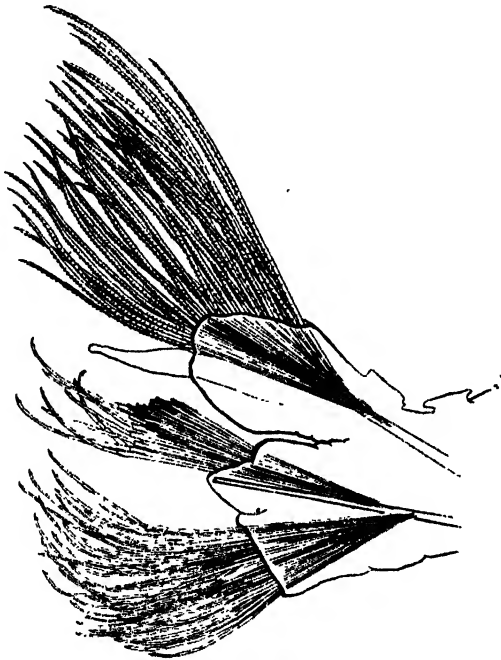
*Occurrence* :—"Sow and Pig's Bank, Port Jackson."

*Description* :—One specimen so much coiled and hardened that exact measurements are very difficult to obtain, but about 25 cm. long by 3 mm. broad, excluding feet. The prostomium is rounded in front, and there are two faintly discernible eye-spots. The lateral tentacles are reduced to small papillæ, as is usual in the genus, and there is no median tentacle. Below the prostomium there is a small conical tubercle lying between and slightly ventral to the long, smooth, flagelliform palps. Immediately above the latter are the parapodia of the 1st segment, the dorsal and ventral cirri of which are about the same length, this being approximately one-fourth that of the palp. Except in the 1st segment, there is no dorsal

cirrus, and the ventral cirrus, which in the 2nd foot is fairly long and reaches to the tips of the ventralmost chaetæ, diminishes in size until the 6th foot, where it reaches to the tip of the ventral lobe of the foot, as it does in the remaining feet.

The ciliated cirriform branchia, which is attached either to the dorsal tubercle or to the point of junction between elyrophore and elytron, exists as a slender papilla on the 3rd and 4th segments, reaches its full development at the 5th foot, and continues on every segment to the end of the body. The foot consists of a notopodium with three ctenidia on its upper

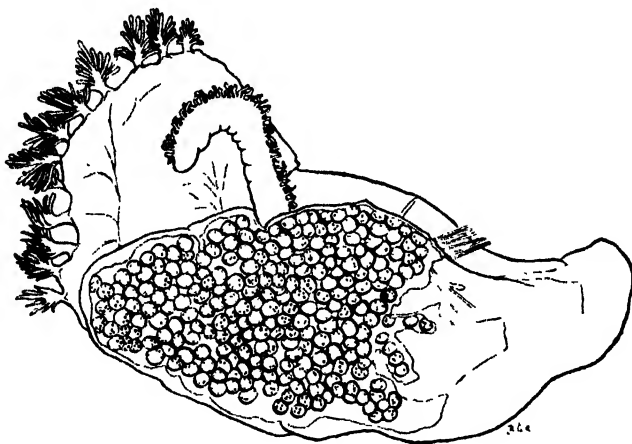
FIG. 10.

*Sigalion ovigerum*, sp. n.Anterior foot.  $\times 30$ .

surface and a long cirriform stylode growing from its apex, and of a neuropodium with a flattened leaf-like papilla on its upper surface which becomes more rounded and shorter in the posterior segments. The chaetæ of the 1st segment, which are divided into two tufts, the dorsal one directed upwards and the ventral forwards, are all of the same kind and similar to the notopodial chaetæ of the other feet. They are long, slender, and capillary, with numerous rows of fine teeth and a forked tip (fig. 10). The neuropodial chaetæ are divided into two tufts, of which the upper contains two kinds of chaetæ. The most dorsal of these are a few moderately stout

bristles with a row of strong teeth on either side. These taper to a fine point. Below them are a number of compound chætæ, of which the head of the shaft is lightly toothed, and the blade containing many joints set close together ends in the usual beak-like apex. The ventralmost tuft is, except for a few bristles on the edge of the bundle which are shorter than the others, composed of long, fine, many-jointed compound chætæ of a very delicate sort. In these the joints of the blade are set much further apart and the head of the shaft is without teeth. They also end in a beak-like apex. With regard to the acicula, I could observe only a single stout dark brown aciculum in the first chaetiger, the remaining segments of the body having two—a dorsal and a ventral. The elytra, which in the anterior segments of the body are thin, smooth, semi-rectangular

FIG. 11.

*Sigalion ovigerum*, sp. n.

Modified elytron from sexual region, seen from ventral surface.  $\times 25$ .

structures, are furnished on their posterior lateral border with about a dozen pinnate papillæ, the centralmost of which have 10–12 branches. The elytra occur on the 2nd, 4th, 5th, 7th, and on every alternate segment up to the 27th, after which they occur on every segment.

In the posterior two-thirds of the body they undergo a great modification, becoming swollen sacs full of eggs (fig. 11). The significance of this modification is discussed below.

*Remarks*:—The two other species of *Sigalion* recorded from the Indo-Pacific area are *Sigalion amboinense*, Grube, from which this species differs in possessing parapodial ctenidia, and *Sigalion bandaensis*, Horst, from which I have some hesitation in separating it. *S. ovigerum* differs in the following characters:—The dorsal and ventral tentacular cirri are of much the same

length, while in Horst's species the dorsal is shorter than the ventral. The number of papillæ on the elytra is never less than ten, nor is the number of their branches in the centrally-placed ones ever as low as three. Moreover, Horst makes no mention of the rudimentary gill on the 3rd and 4th segments. Horst's species has only two simple toothed chaetæ in the upper part of the neuropodial fascicle, while *S. ovigerum* has about a dozen. Furthermore, I could observe no compound chaetæ with simple appendixes, such as Horst describes for his species. Until we possess more material from the Indo-Pacific for comparison, it is preferable to keep these two species apart.

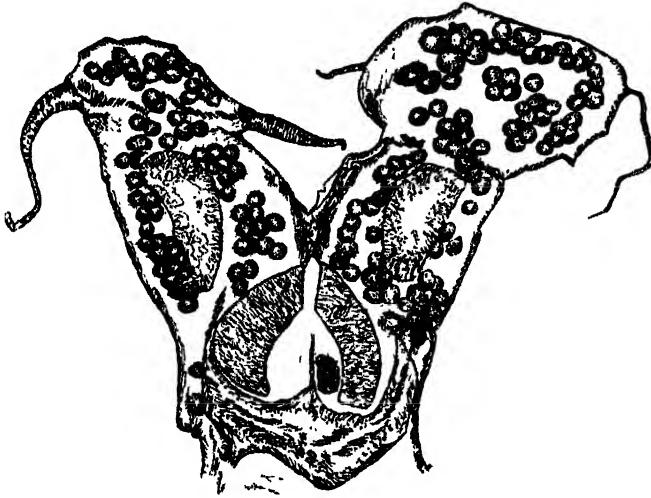
With regard to the transformation of the elytra in the sexual segments into vesicles, until this phenomenon has been observed on the living animal, no very definite conclusion can be safely drawn. For it is possible that the body-wall of the animal during its death struggle may have contracted with such violence as to force the coelomic products up through the elytophores and to tear the two layers of the elytra apart, thus forming what appears to be an egg-sac. The phenomenon, although it may be traumatic in origin, is of sufficient interest to justify a very brief review of the opinions held by various authors on the morphological relations of the elytron. Quatrefages, Grube, and others assumed that the elytron is simply a flattened sac, between the two walls of which there is a cavity in communication with the general coelomic cavity. In support of this, Johnson (1839, p. 425) and Costa (1841, p. 269) both claimed to have observed cases of elytra being filled with eggs. Haswell, however, examined the relations of the elytra carefully, and came to the conclusion that the elytron is a purely epidermal structure, a simple evagination of the integument, and therefore contains no coelomic cavity (Haswell, 1883, p. 251). He regards those cases recorded of the elytra being distended and globular as "due to a forcible rupture tearing the two layers of the scale apart and producing a permanent malformation." In his view the elytron consists of cuticle, a double layer of cells or cell equivalents, and a fibrous layer which firmly unites the upper and under walls together. He adds that the fibrous tissue appears morphologically to represent the muscular layer of the integument. Jourdan (1885, p. 134) holds that the fibrous tissue of the elytra represents an anatomical element differing both from muscular tissue and from connective tissue, and that it belongs to that class of epidermal inter-epithelial structures, among which are found the basal membranes, limiting membranes, etc.

Darboux (1900, p. 157) also asserts categorically that the elytron is exclusively epidermal. Duncker (1906, p. 191), in his elaborate study, confirms Darboux and others in their observations that the elytron is composed of two epithelial layers covered with a chitin cuticle on the outside and united on the inside by an interlacing network of fibrous

tissue, the histology of which requires elucidation. He further emphatically states that there is no possible communication between the elytron and the coelom, and takes Haswell's view of the cases recorded of elytra being vesicular and filled with fluid etc.

A study of sections of some sexual segments of *Sigalion ovigerum* clearly shows the ova, which pack all the cavity of the elyrophore not occupied by the intestinal diverticula, breaking through the coelomic epithelium which lines the roof of the elyrophore and pushing up into the fibrous tissue of the elytron (fig. 12). As more eggs pass up the elyrophore and into the elytron, the roof of the latter is forced further up, and the fibrous tissue splits further and further outwards towards the edge of the elytron. So a sac is formed.

FIG. 12.

*Sigalion ovigerum*, sp. n.

Transverse section through sexual region, showing the ova which pack the coelomic lumen of the elyrophore passing up into the cavity formed by the separation of the upper and lower layers of the elytron.  $\times 24$ .

It appears to me that there has been no violent muscular contraction causing a sudden rupturing of the elytra, but that the ova have simply pushed their way through the intervening tissue, being forced up by pressure of coelomic fluid. Darboux (*loc. cit.* p. 157) comments on the firmness of attachment of the Sigalionid elytron. In the Sigalionidæ "où l'autotomie ne se produit que d'une façon tout à fait exceptionnelle, la base d'insertion est très large; elle comprend toute la surface de l'elyrophore," so that pressure from within is not nearly so likely to cause the elytra to fall off,



as would be the case in most Aphroditacea where the elytra are much more loosely attached. In *Drieschia pellucida*, Moore, the elytra appear normally to be globular and filled with fluid. Moore (1903, p. 196) made this observation on the living animal, and adds that these vesicular elytra are "entirely closed and without communication with the cœlom." In this case the fluid must either have been secreted by the walls of the elytra, or absorbed in some way from the surrounding medium. I think it more probable that Moore was mistaken, and that the fluid in question was of cœlomic origin. Precisely the same considerations apply to the genus *Plotolepis*, Chamberlin (1919, p. 40), where the elytra are inflated and vesicular and probably act as floats.

*Summary*:—The conclusion of Haswell, Darboux, and Duncker that there can be no communication between the elytron and the cœlomic cavity except through a traumatic lesion is not wholly justified. Although the evidence at present is insufficient to form a definite conclusion, it may be that in some few species the tissue which separates the cœlom from the inner surface of the elytron is normally broken down, the pressure of the cœlomic fluid causing a cavity to be formed inside the elytron, which thus becomes part of the general body-cavity.

#### EUTHALANESSA OCULATA, McIntosh.

*Euthalanessa oculata*, McIntosh, 1885, p. 142, pl. 21. figs. 1 & 2, pl. 23. fig. 12, pl. 25. fig. 3, pl. 13 A, figs. 11-12.

*E. oculata*, Horst, 1917, p. 107, pl. 22. figs. 1-3.

*Occurrence*:—"Thursday Island, Torres Straits, 4-7 fms., sand." "Prince of Wales Channel, 7 fms., sand." "Macclesfield Bank, China Sea, 30-50 fms."

*Remarks*:—One large specimen  $146 \times 6$  mm., including feet, and ten fragmentary ones. In all the eleven specimens the chætæ are very much damaged, so that I was unable to observe any of the many-jointed type of ventral chætæ. My specimens correspond closely to McIntosh's and to Horst's description and figures. The four digitiform stylodes which Horst describes arising from the dorsum of the neuropodium are only present in the most anterior feet.

#### STHENELAIS VARIABILIS, Potts, var. COLORATA, var. nov.

*Occurrence*:—"Port Denison, E. Australia, sand and shell, 4 fms."

*Remarks*:—One anterior fragment 41 mm. long by 8 mm. broad, including the feet. There are 33 segments in all. The presence in the upper part of the neuropodial fascicle in the more posterior segments of a pair of simple spinous chætæ followed by one or two long-jointed compound chætæ with spinous shafts refers this specimen to *S. variabilis*. The base of the median

tentacle is grooved and the ctenidia hide the anterior pair of eyes, which are quite lateral. The difference between the dorsal and ventral tentacular cirri is not great, the latter being about two-thirds the length of the former. The neuropodium is furnished with a "bractée parapodiale" and the stylodes are very numerous. The elytra are fringed on their external border with a number of small tubercles, among which near the edges are found a few blunt spines. All the elytra except the most anterior are peppered with small spots of dark pigment which on examination proves to be little circular patches of pigment surrounding the bases of the tubercles. This pigment first appears on the 13th elytron on the right side and on the 18th on the left side, thus giving the worm a curiously asymmetrical appearance.

### Family EUNICIDÆ.

#### EUNICE ANTENNATA, Sav.

For synonymy see Fauvel (1917, p. 225).

*Occurrence* :—"Port Molle, beach and coral reef." "Port Denison, sand and shell, 4 fms." "Prince of Wales Channel, sand, 7 fms." "Thursday Island, sand, 4-7 fms." "Isle des Neufs, the Maldives."

*Remarks* :—Seventy-eight specimens in all. The largest complete specimen is  $112 \times 5$  mm., excluding feet—that is to say, they are small compared with their more northern relatives. The gills begin in the great majority of cases on the 5th chaetiger, but of the 78 specimens examined only 9 show the gill beginning on the 4th chaetiger. Four have the gill beginning with several filaments on the 6th chaetiger, but this is probably due to the loss of the normal single filament on the 5th chaetiger. About 14 is the maximum number of gill filaments shown by the largest specimen, and in the smallest specimen this may drop to 4. In about 15 per cent. of the specimens I could detect no increase of size and number of gill filaments in the posterior third of the body, and I was unable to see any other difference in character correlated with this. It may represent a stage in the animal's growth.

In the young specimens certain characters are noticeable. The tentacles are even more clearly moniliform than in the adult, though none of my specimens showed anything but a strong segmentation of those organs. The prostomium is more prominent than in the adult, and the buccal segment does not cover the eyes. The body appears less strongly dorsally arched and ventrally flattened, and is throughout more cylindrical in shape. In the adult the first six chaetigers are considerably longer than those that follow, but in the young the change is not so much marked. Moreover, in the young the gills and cirri appear stiffer than in the adult. The differences in the figures of the acicular chaetæ given by Crossland (1904, p. 316), by Gravier (1900, p. 255, as *E. flaccida*), by Benham (1915, pl. 41. figs. 67-78, as *E. bassensis*), and by Fauvel (1917, p. 225) are not more considerable than

may be observed in half-a-dozen specimens from the same locality. The slight differences in length of the tentacles, tentacular cirri, and cirri are of no value as a guide to specific differentiation since they are a matter of individual variation. The jaws have been well figured by Crossland (1904, p. 315). The number of teeth of the proximal paired plates varies between 5 and 6, that of the unpaired plate between 6 and 7, that of the left distal paired plate between 6 and 8, and that of the right distal paired plate between 7 and 10.

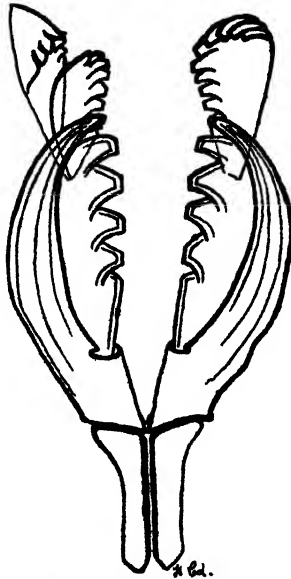
**EUNICE LITA** (Chamberlin).

*Leodice lita* Chamberlin, 1919, p. 240, pl. 54. figs. 6-10, and pl. 55. figs. 1-7.

*Occurrence* :—"Macclesfield Bank, China Sea, 30-50 fms."

*Description* :—One complete specimen and 3 fragments, the former being 130 mm. long and 4 mm. wide in the anterior region and 2 mm. wide in the posterior sexual region, excluding the feet.

FIG. 13.



*Eunice lita* (Chamberlin).

Upper jaw plates.  $\times 23$ .

The body is composed of two distinct regions—an anterior one of about 100 segments and 50 mm. in length, and a posterior one in which the body shows marked differences. Anteriorly it is subcylindrical, dorsally strongly arched, widest at about the 15th segment, the body-wall thick, tough, and resistant, the colour in spirit a pale ochre; in the posterior region it is flattened ventrally, the body-wall thin, soft, and unresistant, the length of the segments much increased and the width half that of the anterior region, and the colour

in spirit a pale grey. The anterior segments are very short, but at about the 75th segment they begin to lengthen out and reach their maximum length by the 100th segment. The change of character of body cannot be definitely localised, but occurs between the 90th and 110th segments.

The gill begins as a small papilla on the 18th segment and ends on the 121st. It consists throughout of a single filament. I could observe no bifid gills such as Chamberlin describes. For the first few chætigera the dorsal cirrus just surpasses the ends of the dorsal chætæ, and the ventral cirrus is digitiform. At the 6th segment the ventral cirrus begins to acquire the usual secretory pad. At the 20th the gill is the same length as the cirrus, which just falls short of the ends of the chætæ, and the ventral cirrus consists of a secretory pad and a small conical projection. At the 50th chætiger the gill has increased in size, and the dorsal cirrus is reduced by about one-half, the ventral cirrus being as before. At the 100th the gill is much reduced, and the dorsal and ventral cirri are very small and digitiform, the pads having ceased at about the 75th segment. At the 150th the whole foot is much reduced, and by the 200th the ventral cirrus has become a small rounded lobe and the dorsal cirrus is as before. The acicular spine begins on the 24th foot. The chætæ correspond closely to Chamberlin's figures.

The jaws are as shown in the figure (fig. 13). Their formula is as follows: 5-5: 7+5-9.

*Remarks*:—*Eunice lita* shows affinities with *E. viridis*, *E. siciliensis*, and *E. paloloides*, but from all these it is easily distinguishable by the arrangement of the gill alone.

#### EUNICE MICROPION, Marenzeller.

*Eunice micropion*, Marenzeller, 1879, p. 135, pl. 5, fig. 1.

*E. Grubei*, Gravier, 1900, p. 258, pl. 14, figs. 87-88, text-figs. 125-129.

*E. Grubei*, Crossland, 1904, p. 288.

*E. Grubei*, Malaquin and Dehorne, 1907, p. 367, figs. 10-12.

*Occurrence*:—"Port Molle, Queensland, beach and coral reefs." "Macclesfield Bank, China Sea, 30-50 fms."

*Remarks*:—One young specimen 25 mm. long and 3 mm. wide, and 3 anterior fragments, the largest being 58×6 mm. Of the 4 specimens two have the gill beginning on the 4th chætiger and two on the 5th.

In the young specimen the segmentation of the tentacles, tentacular and anterior dorsal cirri is more clearly defined than in the adult, where in respect of the tentacular and dorsal cirri it is difficult to observe. Moreover, the length of the tentacles and tentacular cirri is greater relatively to the length of the buccal and anterior segments in the young than in the adult. In the young specimen the median tentacle reaches to the middle of the 8th chætiger, the two inner laterals to the 5th, while in the adult the median tentacle reaches to the 3rd and the two inner laterals to the 2nd chætigers. The acicular chæta begins about the 30th segment. The jaws correspond closely

to Gravier's description. The following are two formulæ : 5-4 : 6+5-9 and 5-5 : 6+6-9.

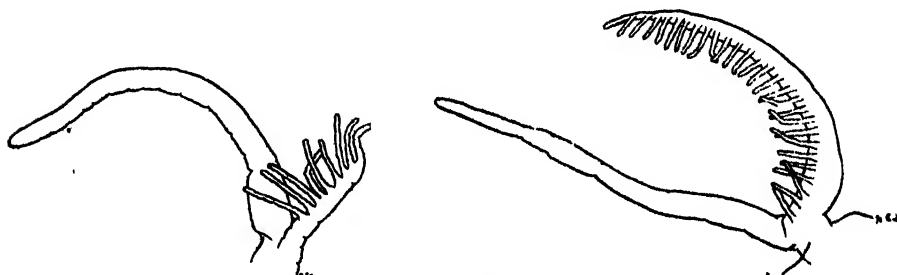
*Remarks* :—I am unable to detect any differences of specific value between *E. micropion*, Marenzeller, and *E. Grubei*, Gravier.

*EUNICE FRANKLINI*, sp. n.

*Occurrence* :—"The Franklin shoal. Latitude 9° 53' S., Longitude 129° 19' E. in the Arafura Sea."

*Description* :—One specimen 105 mm. long by 8 mm. wide, excluding feet ; 92 chætigers in all. The caudal end is lacking. Colour in spirit ochreous yellow. Highly iridescent. The skin has that tessellated mosaic appearance which is found in several other members of the genus. The median tentacle, which together with the other tentacles shows very faint signs of annulation, reaches, when laid along the back, to the 8th chætiger, the inner laterals to the 4th, the outer laterals to the base of the tentacular cirri, while the latter reach forward a little beyond the bases of the inner laterals. There are two eyes, in

FIGS. 14 & 15.



*Eunice Franklini*, sp. n.

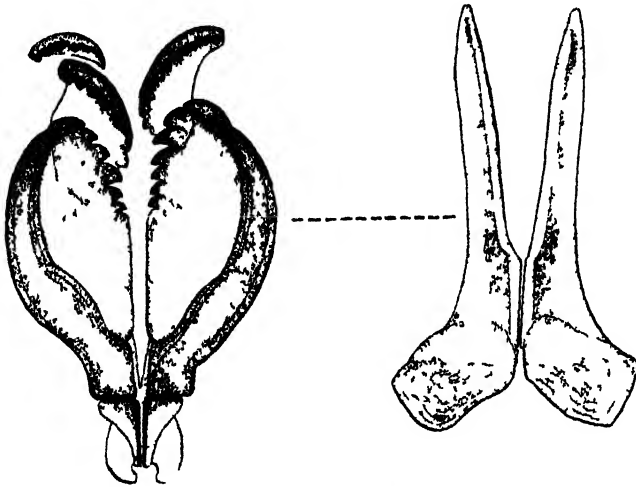
Gill and dorsal cirrus of 6th foot.  
× 12.

Gill and dorsal cirrus of 70th foot.  
× 14.

the shape of a triangle, the apex of which lies between the bases of the inner and outer lateral tentacles. The peristomium, which is separated behind from the second segment by a slight transverse furrow on the dorsal surface, folds over the prostomium, concealing the eyes. The peristomium and the 2nd segment are together equal in length to the first four chætigers. From the 2nd chætiger to the 8th the anterior edge of each segment is folded over the posterior edge of the one in front in a manner similar to that in which the anterior edge of the peristomium folds over the prostomium. The gills begin on the 6th chætiger, with 10 filaments arranged pectinately along a main axis. There are 13 filaments on chætiger 10, 19 on 20, 19 on 30, 20 on 40, 21 on 50, 26 on 60, 27 on 70, and 25 on 92. The gills are remarkable for the shortness of the filaments in relation to the main axis. On the proximal portion of the latter, between the bases of the filaments, there

are a number of clearly-marked, dark-brown, circular pigment-spots. These diminish in size and become fainter towards the distal portion of the gill-axis. The length of the latter continues to increase posteriorly till the 60th chætiger, after which it begins to decline. At the 6th chætiger the gill is 1.2 mm. long, at the 20th 2.6 mm., at the 60th 3.2 mm., and at the 92nd 3 mm., while the length of the filaments remains throughout at about .5 mm. The dorsal cirrus is exceedingly long, being in the anterior segments about four times as long as the gill (fig. 14). It decreases slightly in length posteriorly. Thus, while at the 6th foot it is 4.8 mm. long, at the 60th it is 4 mm. long, and at the 92nd 3.6 mm. It is supported by about 6 chætæ, two of which are black and have the appearance of small acicula. The ventral cirrus is

FIG. 16.

*Eunice lita* (Chamberlain)Upper and lower jaw plates.  $\times 9$ 

finger-shaped for the first four chætigers, then the normal secretory pad appears ornamented by a conical process, which shows considerable increase in size after the 70th chætiger. The chætæ are of three kinds, the dorsal bundle containing long, slender capillaries with minutely hispid edges and comb chætæ similar to those found in *E. tentaculata*. The compound chætæ are hooded bidentate sickles with both the head of the main shaft and the side of the hood striated. There are two black acicula with blunt apices, and a slender acicular chætæ with a bidentate head making an acute angle with the acicula. This acicular chætæ appears between chætigers 30 and 40. With regard to the jaws, the formula is as follows: 6—7 : 8+5—11 (fig. 16).

*Remarks*:—*Eunice Franklini* is closely related both to *E. tentaculata* and to *E. aphroditois*, but in both these species the gill is longer than the dorsal cirrus, while in *E. Franklini* the dorsal cirrus is very much longer than the gill.

**EUNICE SICILIENSIS**, Grube.

For synonymy see Fauvel (1917, p. 281).

*Occurrence* :—"Ile des Neufs and Darros Island, the Amirante Group."  
"Macclesfield Bank, China Sea." "Thursday Island."

*Remarks* :—One young specimen, incomplete posteriorly, measuring 44 mm. long by 2 mm. broad, excluding feet, and seven other specimens, all incomplete. In the young specimens the gills begin on the 83rd chætiger. Although all in a bad state of preservation, the specimens can be easily identified by the absence of the acicular chætæ and of the comb chætæ, combined with the unifilamentous character of the gills.

**EUNICE TUBIFEX**, Crossland.

*Eunice tubifer*, Crossland, 1904, pp. 303-310, pl. 21. figs. 1-8, text-figs. 52-55.

*Occurrence* :—"Tizard Reef, China Sea, 6 fms."

*Description* :—One specimen 52 × 6 mm., excluding feet: the caudal end is lacking. My specimen agrees very closely with Crossland's description and figures. The median tentacle when laid along the back reaches to the 5th, the two inner laterals to the 4th, and the two outer laterals to the 1st chætiger. The peristomium is as long as the four following segments. The gills begin as a small papilla on the 38th chætiger, consist of two small filaments by the 50th, and by the 70th there are three or four fairly large filaments.

In the posterior segments of the body the normal number of acicular chætæ is three.

**DIOPATRA** sp.

*Occurrence* :—"Thursday Island, 4-7 fms., sand."

*Description* :—A single fragmentary specimen, composed of 29 segments, 16 mm. long, excluding the tentacles, by 5 mm. broad, including the feet.

The palps are truncated and mammiform, the mamilla pointing in the antero-lateral direction. The posterior occipital tentacles when laid along the back reach to the 12th chætiger. There are no eyes observable. For the first four chætigera the body is strongly arched dorsally and then suddenly flattens out. There is a dark stripe running up the mid-dorsal line. The first foot is composed of a considerable dorsal cirrus, a rounded chæta sac surmounted by a projecting papilla, and a digitiform ventral cirrus. By the 6th foot the latter disappears, its place being taken by a pad. The chæta-sac papilla diminishes in size posteriorly, and by the 20th foot is reduced to a very small process. In the first four feet there is a single curved, somewhat flattened dorsal chæta tapering to a fine point; as far as could be determined without further material, it has a pseudo-articulation of a similar nature to that existing in the ventral chætæ, but much less distinct (fig. 17). The ventral chætæ are pseudo-compound, hooded, bidentate, yellowish structures.

There are four or five slender chætæ running within and supporting the dorsal cirrus. I was unable to detect any aciculum supporting the chæta sac. At the 5th chætiger the character of the chætæ changes. The dorsal are flattened, tapering blades with a narrow crenulated border. These lie at right angles to the main axis of the body. Amongst them are a few comb chætæ with numerous teeth. The ventral chætæ are shorter than the dorsal; they are broad, flattened, thinly bordered, and tapering to a fine point. They are directed ventro-laterally, and their shafts lie obliquely across the shafts of the dorsal chætæ, their point of origin being slightly dorsal to the notopodial chætæ (fig. 18). More posteriorly there is a further modification of the

FIGS. 17 &amp; 18.

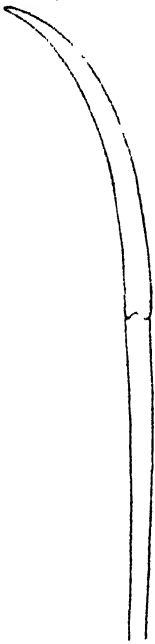
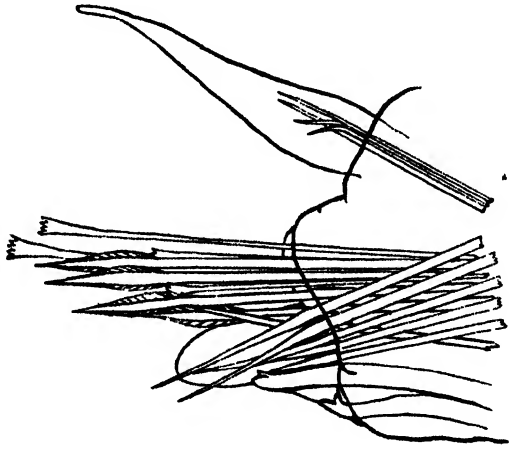


Fig. 17. Dorsal chætæ of 1st foot.  
× 195.



*Diopatra* sp.

Fig. 18. 16th foot. × 80.

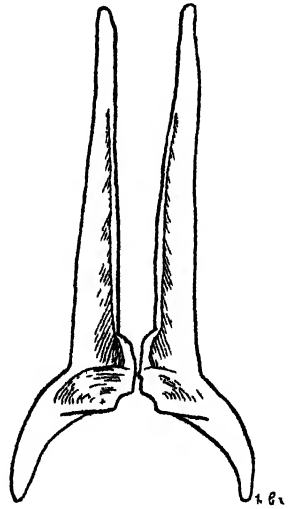
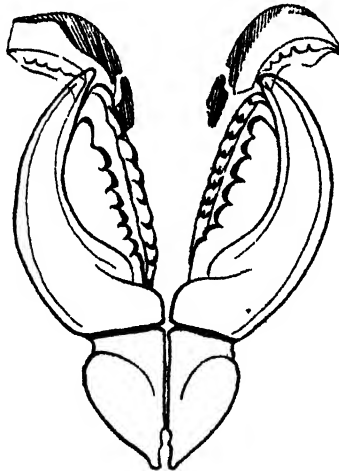
dorsal chætæ. Distally they acquire a wide, striated, wing-like border, which gives them somewhat the appearance of a quill (fig. 19). Moreover, the angle between the shafts of the dorsal and ventral chætæ is increased. About the 12th foot two strong, bidentate, subchætal spines appear which run parallel with the neuropodial chætæ. The gills, which are as in the genus, appear on the 5th chætiger, diminish in size posteriorly, but are still present on the most posterior segment of the fragmentary specimen. With regard to the jaws, which are in a bad state of preservation, the lower jaw plates are very slender and delicate, and the teeth of the proximal paired plates of the upper jaws are sharply defined (see figs. 20 & 21).



There is no unpaired plate. On the right side, corresponding to the normally azygous plate of the left side, is a plate, the teeth of which are rather ill-defined.

*Remarks*:—The genus *Diopatra* is in great need of revision. *D. dentata*, Kinberg, *D. Leuckarti*, Kinberg, *D. amboinensis*, Aud. & Edw., and *D. luzonensis*, Grube, all from the Indo-Pacific, are not at all clearly defined.

FIGS. 19, 20, & 21.



*Diopatra* sp.

Fig. 19. Dorsal chaeta from 25th foot.  $\times 170$ .

Fig. 20. Upper jaw plates.  $\times 22$ .

Fig. 21. Lower jaw plates.  $\times 22$ .

Augener (1922, p. 37), who redescribed at some length a *Diopatra dentata* from Cape Jaubert, W. Australia, proposes to separate them on the number of teeth in the comb chaeta.

As this character in allied genera, e.g. *Marphysa*, varies in the same individual according to the part of the body from which the chaeta is taken, I hesitate, without further evidence, to accept its use as a specific character in *Diopatra*.

**LYSIDICE COLLARIS, Grube.***Lysidice collaris*, Grube, 1869, p. 495.*Occurrence* :—"Port Molle, coral reef." "Thursday Island, 4-7 fms., sand."

*Remarks* :—One specimen, 72 × 3 mm., excluding feet, and two fragments. The median tentacle is slightly larger than the two laterals, and is situated a little in front of them. In this the specimens agree with Crossland's (1903, p. 143) description as opposed to Gravier's (1900, p. 272). I was unable to see the constriction of the basal article of the tentacles which he mentions. The relative proportions of prostomium, peristomium, and 1st segment correspond to his description. The eyes are crescentic, with the concavity directed forwards. As Crossland points out, in the anterior part of the body the dorsal and ventral cirri are much larger than as figured by Gravier. The proportions given in Gravier's figure (1900, p. 273, fig. 144) are, however, correct for the last 30 to 40 segments of the body.

**NICIDION IMOGENA, sp. n.***Occurrence* :—"Hotspur Bank, 36° W., 16° S., off the coast of Brazil."

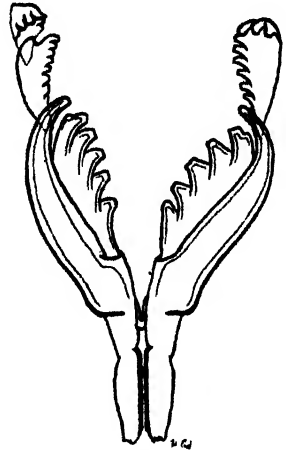
*Description* :—One specimen 25 mm. long by 2 mm. broad, excluding the feet. 108 segments; the caudal end is lacking. Prostomium prominent, divided into two lobes by a median vertical notch, slightly shorter than the peristomium, which is divided from the 2nd segment by a light furrow, scarcely distinguishable on the sides of the body. The peristomium and the 1st segment together equal in length the first three chaetigers. The median tentacle when laid along the back reaches to the 2nd chaetiger, the inner laterals to the anterior border of the 1st chaetiger, the outer laterals cover about half the length of the peristomium. The tentacles are all distinctly but not strongly annulated. The tentacular cirri are very small, about the length of the 2nd segment. The eyes, which are crescentic with the concavity directed forwards, are placed just laterally to the inner lateral tentacles. The body in the anterior segments is subcylindrical, becoming flatter dorso-ventrally towards the middle region. The first eight chaetigers are much longer than those following, which are very short and compressed. They continue thus till the 58th chaetiger, when they begin to lengthen out again, but it is not until the 70th chaetiger that they reach their maximum length; correlated with the change in length of the segments is a considerable difference in the character of the feet. For the first eight chaetigers the dorsal cirrus slightly surpasses the ends of the dorsal chaetæ, and the ventral cirrus is digitiform. At the 20th foot the dorsal cirrus is reduced, and the ventral cirrus has formed a pad with a conical projection at the apex. By the 40th foot the dorsal cirrus is still further reduced, and the ventral is almost entirely absorbed into the pad, only a small projection remaining. At the 70th chaetiger the dorsal cirrus is as at the 40th, but the ventral cirrus has once more become a small digitiform process, the pad having disappeared.

By the 100th foot the cirri have dwindled into mere papillæ, and the aciculum and acicular spine are very prominent.

The dorsal bundle of chætæ contains two kinds: one, fine tapering capillary with a minutely hispid edge (fig. 22); the other, comb chætæ with fairly numerous teeth, the terminal one being prolonged.

The ventral bundle is composed of compound chætæ. The head of the shaft is spoon-shaped in outline and delicately striated, and the blade is hooded and bidentate (fig. 23). There is a single dark brown bluntly acuminate

Figs. 22, 23, & 24.



*Nicidion imogena*, sp. n.

Dorsal chaeta from anterior  
foot.  $\times 600$ .

Ventral chaeta from anterior  
foot.  $\times 1200$ .

Upper jaw plates.  
 $\times 54$ .

aciculum and a hooded bidentate acicular spine, which begins between the 50th and 55th chætiger. The jaws are as shown in the figure (fig. 24). The formula is as follows: 4-4:7+5?-9. I failed to observe any paragnaths.

*Remarks*:—*Nicidion imogena* is related both to *Nicidion brevis*, Ehlers, and to *Nicidion gracilis*, Crossland, but differs chiefly in the much larger number of segments involved in the compressed pad-bearing anterior region of the body.

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On the Polychæta collected by H.M.S. 'Alert,' 1878-1882. Families Aphroditidæ and Amphinomidæ. By C. C. A. MONRO, F.I.S.

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(With 7 Text-figures.)

[Read 5th June, 1924.]

### Family APHRODITIDÆ.

#### LÆTMONICE BREVEPINNATA, Horst.

*Lætmonice brevepinnata*, Horst, 1917, p. 57, pl. 13. fig. 13.

*Occurrence*:—"Kowloon Bay, Hong Kong, 5 fms."

*Description*:—Two specimens. The larger 16 mm.  $\times$  6 mm., the smaller 13 mm.  $\times$  4 mm., both measurements excluding the feet. The absence of felting, the small appendage at the end of the ventral foot, and the curious ventral chætæ with teeth and abbreviated pinnæ are diagnostic of this species. There are 34 segments and 15 pairs of very large imbricating

FIG. 1.



*Lætmonice brevepinnata*, Horst.  
Head of dorsal chæta.  $\times$  312.

elytra. The eye peduncles, which are totally devoid of eye pigment, are half the length of the median tentaculophore. The palps reach to the 9th chætiger, and the median tentacle is about two-thirds of their length. The tentacular cirri are slightly shorter than the tentacle. The dorsal cirri are

very long, becoming longer towards the posterior end of the body, where they are more than twice as long as the dorsal chætæ. Both tentacle and dorsal cirri have clavate tips. The ventral cirrus is as described and figured by Horst. The tips of the dorsal chætæ are in some cases enclosed in a valve. Below the hastate apex there are usually three fangs on one side and two on the other (fig. 1). With regard to the neuropodia, there are the usual bipinnate chætæ in the first few segments. The long ventral chætæ show considerable variation not only in the same individual, but in the same foot. There are four principal types: chætæ which are apparently perfectly smooth above the great fang, chætæ with two to four small teeth above the great fang and no abbreviated pinnæ, chætæ with the above number of teeth and distal to them a row of abbreviated pinnæ, and lastly, chætæ with abbreviated pinnæ alone above the great fang (fig. 2).

FIG. 2.



*Lætmonice brevipinnata*, Horst.

Ventral chætæ. B, C, and D all from the same foot.

A  $\times 165$ . B  $\times 122$ . C  $\times 144$ . D  $\times 150$ .

*Remarks*:—This species is very close to *Lætmonice rugosa*, Horst, from which it differs in the possession of a dorsal felting and in the absence of tubercles from the shaft of the dorsal chætæ.

The ventral chætæ appear to be intermediate between those found in *Hermione* and those in *Lætmonice*.

**APHROGENIA NIGROPUNCTATA**, Horst.

*Aphrogenia nigropunctata*, Horst, 1917, p. 64, pl. 14. fig. 13.

*Occurrence*:—"Thursday Island, Torres Straits."

*Description*:—One specimen, consisting of 28 segments and measuring 14 mm. in length and 6 mm. in breadth at its widest part, excluding the feet. The diagnostic character of this species appears to be the presence of black spots on the dorsal surface of the feet of the cirriferous segments. The median tentacle is missing, and the palps when laid along the back reach to the 7th chaetiger. The dorsal tentacular cirri are about three-quarters the length of the palps, the ventral half their length. The dorsal cirri are very long, while the ventral do not reach the end of the foot. An elytron from the centre of the body is roughly in the form of an isosceles triangle, the base of which is formed by the elytron's external margin, while its apex lies transversely to the main axis of the body. In the centre of the external margin near the point of attachment is a concavity, so to speak, cut out to receive the fascicle of curved dorsal chaetæ. The elytra are of a nacreous silver colour, and the radial striation is marked especially towards the edges. They are exceedingly firmly attached, the elyrophore being very large, so that it is impossible to pull one away from the body without at the same time tearing away strands of muscle from the elyrophore. The refractive coarse tubercles are not present on the tip of all the curved dorsal chaetæ, their place being taken by a cap of villi.

PONTOGENIA MCINTOSH, nom. nov.

*Palmyra aurifera*, Savigny, of McIntosh, 1885, p. 53, pl. 9, figs. 1-2 etc.

" " Savigny, of Izuka, 1912, p. 94.

" " Savigny, of Treadwell, 1920, p. 592.

[Non *Palmyra aurifera*, Savigny, 1822, p. 16.]

*Occurrence*:—"Macclesfield Bank, China Sea, 30-45 fms."

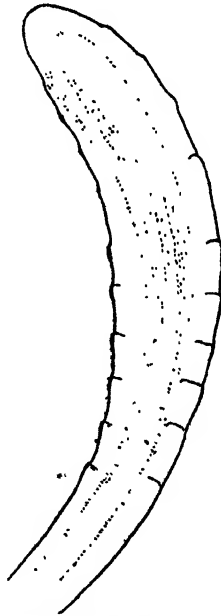
*Description*:—Eight specimens, the largest being 16 mm.  $\times$  6 mm. and the smallest 9 mm.  $\times$  4 mm., both measurements excluding the feet. The number of segments is 34-36, and there are 15 pairs of elytra on the 2nd, 4th, 5th, and the succeeding alternate segments, as in Grube's re-definition of the genus. The median tentacle is only one-third the length of the palps, and is slightly shorter than the tentacular cirri. The ventral cirrus of the 2nd chaetiger is modified, and resembles the tentacular cirrus, the remaining ventral cirri being very short. The tentacle and all the cirri are four-jointed as in *P. chrysocoma*, and the long mushroom-shaped papillæ are spread over the basal joint of the tentacle and dorsal cirri. The elytra are simple oval membranous structures without processes of any kind. The neuropodia of the 2nd and 3rd segments show bipinnate bristles similar to the one figured by Potts (1910, pl. 21, fig. 34) for *Palmyra splendens*. The palæ (fig. 3) are broader than those described by McIntosh, and the alternately-arranged serrations are in the form of transverse ridges. The capillary chaetæ are so much covered with detritus that it is impossible to distinguish any processes on them.



*Remarks*:—I accept Augener's (1913, p. 81) and Horst's (1917, p. 61) conclusions as to the non-identity of McIntosh's species with that of Savigny. Horst affirms that the dorsal bristles of McIntosh's (1885, pl. 6. A, fig. 8) do not agree with those figured by Andouin and Milne Edwards (1834, pl. 2. A, fig. 4). However, an examination of McIntosh's specimen shows that its palæ differ little, if at all, from those figured by Andouin and Milne Edwards. A detailed comparison is impossible, for the palæ of the French author's specimens are not figured at a sufficient magnification.

*Pontogenia McIntoshi* is very close to Horst's *Pontogenia nuda*. It differs, however, in the respect that there is no concavity in the posterior margin of

FIG. 3.

*Pontogenia McIntoshi*, nom. nov.Palæ.  $\times 85$ .

the elytra. Moreover, the palæ appear to be much broader and more curved. The species of *Pontogenia* which are without a dorsal felting can apparently be distinguished from *Palmyra* only by the presence of elytra and elytraphores.

#### PONTOGENESSA, gen. nov.

*Generic definition*.—As *Pontogenia* except that the neuropodial chætæ are simple and not bifid, lacking the lateral spur.

Genotype, *P. obscura*, sp. n.

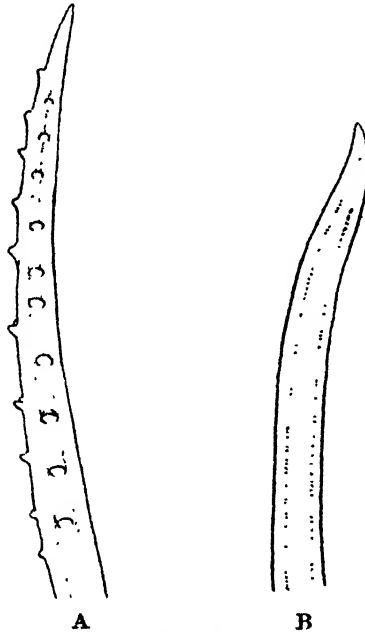
#### PONTOGENESSA OBSCURA, sp. n.

*Occurrence*:—"Macclesfield Bank, China Sea, 50-60 fms."

*Description*:—Five specimens, the largest of which is 29 mm.  $\times$  7 mm., and the smallest 15 mm.  $\times$  7 mm., both measurements excluding the chætæ.

Colour in spirit pale yellow and the golden paleæ conspicuous. There are between 50 and 60 segments and 18 pairs of elytra. The body is subrectangular in section and the prostomium rounded. There are two pairs of closely-approximated eyes set on the end of long peduncles. The median tentacle is long, filiform, and quadriarticular. The palps are stout, shorter than the median tentacle, and beset with hook-shaped processes. Both dorsal and ventral tentacular cirri resemble the median tentacle in structure, but are shorter, being about equal in length to the palpi. The dorsal cirri are similar, and the ventral cirri are very short and stout, with a small filiform terminal appendage. The elytra are simple membranous structures without processes of any sort. The back is covered with a hedge of golden paleæ, below which lies a thin felting of capillary chætæ. The paleæ are yellow, slightly curved, tapering to a point and covered with a number of strong cusps, usually arranged in two alternating rows (fig. 4 A).

FIG. 4.

*Pontogenessa obscura*, sp. n.A. Dorsal chæta.  $\times 90$ .B. Ventral chæta.  $\times 240$ .

There are the usual two kinds of dorsal chætæ, jointed and unjointed capillaries. The neuropodial chætæ are simple structures with a hook-like apex without any secondary tooth or spur (fig. 4 B). There is a pair of short, rounded, clavate pygidial styles.

*Remarks*:—It is possible that the young of this species have the ventral bristles pinnate as in *Aphrodite*, where all trace of the pinnæ is often lost in the adult. My specimens, however, showed no sign of any such processes.

## Family AMPHINOMIDÆ.

## AMPHINOME JUKESSI, Baird.

*Amphinome Jukessi*, Baird, 1870, p. 218, pl. 4. figs. 2 *a*, *b*.

*A. nitida*, Haswell, 1878, pp. 341-342.

*A. pulchra*, Horst, 1912, p. 40, pl. 10. figs. 21-23.

*Occurrence* :—"North-West Australia." Five specimens.

*Description* :—The largest is 20 mm.  $\times$  3 mm. and the smallest 14 mm.  $\times$  2 mm., both measurements excluding the chætæ. The number of segments varies between 35 and 30. The caruncle, which does not extend beyond the first chætiger, and the prostomium are black, and the colour of the dorsal surface is cinnamon-drab and that of the ventral yellowish. The tentacles and cirri are orange, and the gills dark green with pale orange tips. Both dorsal and ventral surface are very much wrinkled, the former in some specimens being crossed by a large number of delicate transverse grooves. This character is, however, absent in some specimens. The chætæ are as described by Horst. The curved notopodial chætæ are apparently delicately serrated on their convex side. The small spines with dilated tip (Horst, pl. 10. fig. 23) are easily overlooked, as they are very closely imbedded in the foot. Both Baird and Haswell make no mention of them.

*Remarks* :—I have examined Baird's type-specimen from Raine's Islet, and the harpoon-shaped chætæ with a row of small denticles on either side, present in Haswell's species and in Horst's, and of which Baird makes no mention in his description, are clearly visible. Therefore, there appears to be no ground for keeping these three species separate. The fact that the curved ventral chætæ in Haswell's specimen had a more acute point than that figured by Baird in his species is a difference that might be due either to wearing, preservation, or mounting. Horst mentions that his species is allied to Haswell's, but gives no reason for separating them.

Furthermore, there is seemingly no good ground, except that of great difference in size, for separating this species from *Amphinome rostrata*, Baird, known from the same faunistic area. I think it probable that this species will prove to be the young form of *A. rostrata*.

## HERMODICE CARUNCULATA (Pallas).

Two specimens, 33  $\times$  5 mm. and 23  $\times$  3 mm., excluding the chætæ.  
"Madeira, 35 fms., sand."

## EURYTHOE COMPLANATA (Pallas).

*Occurrence* :—"Port Molle, beach and coral reef." Seven full-grown specimens and four young. "Christmas Island." Two specimens. "Seychelles." One specimen. "Rameswaram, Gulf of Manaar." Five specimens. "Mozambique." Three specimens.

*Remarks* :—The size of the full-grown specimens is about 120 mm.  $\times$  12 mm., excluding the feet, and that of the young 30 mm.  $\times$  5 mm. The smallest is 15 mm.  $\times$  3 mm.

There is nothing to add to the numerous studies of this species. Horst (1912, p. 35) states that Gravier (1901, p. 251, fig. 265) has overlooked the serrations in the finer type of bifid neuropodial chaetæ. I was also unable to observe any serrations in these chaetæ. It is true that the preservation of my material was not very good, but it may be that the presence of this character is not constant in the species. The coarser type of bifid ventral chaetæ were also quite smooth in my specimens.

In one of the specimens from Seychelles the anterior end of the body was undergoing regeneration.

### CHLOEIA FLAVA (Pallas).

*Chloeia flava* (Pallas), McIntosh, 1885, p. 8, pl. 3. fig. 1 etc.

*Occurrence* :—South Japan, 33° 15' N., 129° 5' E. "Torres Straits Islands." "Thursday Island." "Inland Sea of Japan." "Holothuria bank, Torres Straits." "Dinner Island, New Guinea." Seven specimens.

*Size* :—The transverse measurements are in every case exclusive of the feet. The largest specimen is 99 mm.  $\times$  13 mm. and the smallest is 33 mm.  $\times$  11 mm. The remainder are all between 75 and 80 mm. long and about 15 mm. broad.

*Description*.—This species exhibits wide variations both in body-colour and in the arrangement of the pigment pattern. The body-colour varies from a deep reddish brown to pale yellow, the commonest tint, from flesh-colour to a kind of ashen grey. The chaetæ also, viewed macroscopically, vary from an almost pure white to a bright yellow, and in one specimen from Thursday Island they are pale green. The variations in the arrangement of the pigment pattern are equally wide. The median dorsal purple spots vary in shape from a narrow ellipse to a circle. The deep band of pigment on the anterior surface of the feet from the gill outwards is strongly marked in some specimens and either very faint or wholly absent in others. The pigmentation of the tentacles and dorsal cirri varies from a thin violet line running up their dorsal surfaces to an almost complete covering of deep purple pigment. The branchiae vary from being completely unpigmented to a deep brown on the posterior surface of the branchioles. There is often in each segment in front of the dorsal spot a fainter colour-pattern. This is represented in one of the Japanese specimens, on which McIntosh's study of this species (1885, p. 8, pl. 3. figs. 1 & 3, pl. 1 A, figs. 7-9) was based, by a faint transverse brown band. In one of my specimens it takes the form of an orange-coloured arc around the median spot. In another there are two pale violet circular pigment patches situated on either side of the anterior end of the main spot. This secondary pigmentation is sometimes wholly absent. As regards the feet, the chaetæ show many

stages of disintegration. There seems to be some variation in the number of anterior segments in which the dorsal bifid chaetæ occur. In some, as far as the defective material permitted observation, they appeared to cease on the 3rd-4th segments, and on others on the 7th-8th. In structure they correspond closely to McIntosh's (*loc. cit.*) figures.

*Remarks*:—Horst, in 'Notes from the Leyden Museum,' vol. xxxii. 1910, pp. 169-175, creates three new species of *Chloeia*, which he incorporates in his admirable report on the 'Siboga' "Amphinomids," *C. amphora*, *C. conspicua*, and *C. violacea*, all from the neighbourhood of the Dutch East Indies. He discriminates his species by the arrangement of the pigment pattern and by minor differences in the chaetæ, such as variations in the relative length of the two arms of the bifid bristles. The latter character, taking into consideration the notorious susceptibility of the chaetæ of this family to traces of acid in the preservative, together with the limits of individual variation, is not very satisfactory.

Besides these three species of Horst, there are three more species, all from the same faunistic area—*C. pulchella*, Baird, from N.E. Australia, *C. parva*, Baird (*C. merguiensis*, Beddard), from the Mergui Archipelago and New Guinea, and *C. Macleayi*, Haswell, from N.E. Australia. A wide range of material would have to be examined before any definite conclusion could be reached, but it appears not improbable that these six species are colour-varieties of *Chloeia flava*.

#### CHLOEIA FUSCA, McIntosh.

*Chloeia fusca*, McIntosh, 1885, p. 14, pl. 2. figs. 1 & 2 etc.

" " Potts, 1909, p. 356, pl. 45. figs. 1 & 2.

" " Horst, 1912, p. 22, pl. 7. fig. 6.

*Occurrence*:—"Evans Bank, 12-15 fms." (Latitude 9° 53' S., Longitude 129° 32' E., N. Australia). "Macclesfield Bank, China Sea, 30-36 fms."

*Remarks*:—Three specimens. The largest measures 15 mm. × 5 mm. and the smallest, a young specimen, 6 mm. × 4 mm., both measurements excluding the chaetæ. My specimens correspond closely with McIntosh's and Potts's descriptions and figures. The pigment pattern is confined to the two parallel longitudinal stripes. The two eyes on either side of the prostomium are not discontinuous but fused. The body-colour of the young specimen from the Macclesfield Bank is almost pure white, as are the long bushy chaetæ. There is nothing to add to the very full description of this species given by the authors quoted.

#### PHERECARDIA STRIATA (Kinberg).

*Hermodice striata* Kinberg, 1857, p. 13, and 1858-1910, p. 35, pl. 12. fig. 8.

*Pherecardia lobata*, Horst, 1886, p. 165, pl. 7. figs. 10-14.

*Eucarunculata Grubei*, Malaquin & Dehorne, 1906, p. 358, pl. 51. fig. 2 etc.

*Amphinoma sericata*, Fischli, 1903, p. 95, pl. 4. figs. 1 & 2 etc.

*Occurrence*:—"Macclesfield Bank, China Sea, 31 fms."

*Remarks* :—One specimen,  $27 \times 5$  mm., excluding the feet. The presence of a very large caruncle with its lateral branches dividing towards the tail, which almost conceals the prostomium, the purple striping on the dorsum, and the absence of bifid bristles, assign this specimen to the above species. The prostomium is round and the anterior pair of eyes very large and circular. The caruncle covers the whole width of the dorsum from gill to gill. The pigmentation is confined to a delicate purple striping on the back, the coloration of the bases of the gills, and a thin line running along the lateral lamellæ of the caruncle.

A study of Kinberg's figures leaves no doubt that this was the species which he was describing.

*Pherecardia parva*, sp. n.

*Occurrence* :—"Macclesfield Bank, China Sea."

*Description* :—One specimen, 15 mm.  $\times$  2 mm., excluding the feet. Colour in spirit a very pale yellow, with no pigment pattern of any sort. The prostomium is trapezoidal, and of the two pairs of eyes the anterior is the largest. The prostomium is free from the caruncle, which begins at its posterior border and reaches to the 4th segment. The caruncle is provided with 5-6 lamellæ on each side, and I could observe no secondary pinnate branching such as is found in *P. striata*. The median tentacle is long, reaching just short of the end of the caruncle. Both lateral tentacles and palps are about half this length. The cirri are jointed, the dorsal being about two-thirds the length of the notopodial chætæ, and the ventral half the length of the neuropodials. The gills are large and conspicuous, with stout filaments, and there is a single pygidial appendage. There seems to be nothing about the chætæ to distinguish them from *Pherecardia striata*.

*Remarks* :—This species differs from *P. striata* in the following characters : in the absence of any pigmentation, in the fact that the caruncle is inserted behind the prostomium and not upon it, in the greater relative length of the median tentacle, and in the greater relative size of the gills.

*Notopygus andrewsi*, sp. n.

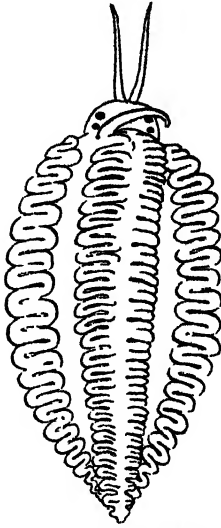
*Occurrence* :—Christmas Island. Two specimens. Collected by the late Dr. C. W. Andrews, F.R.S.

*Description* :—Size 57 mm.  $\times$  6 mm. and 41 mm.  $\times$  8 mm., excluding the feet.

This species resembles *Notopygus Gardineri* in being flatter ventrally than most of the other members of the genus. The long bristling tufts of chætæ are pale yellow. The prostomium is trapezoidal, and the anterior pair of eyes is the larger. In front of the prostomium, on the plate formed by the fusion of the front ends of the labial folds, is a longitudinal streak of brown pigment which widens out anteriorly. The caruncle is inserted in the centre of the prostomium (fig. 5), and in front of it is the median tentacle, which is

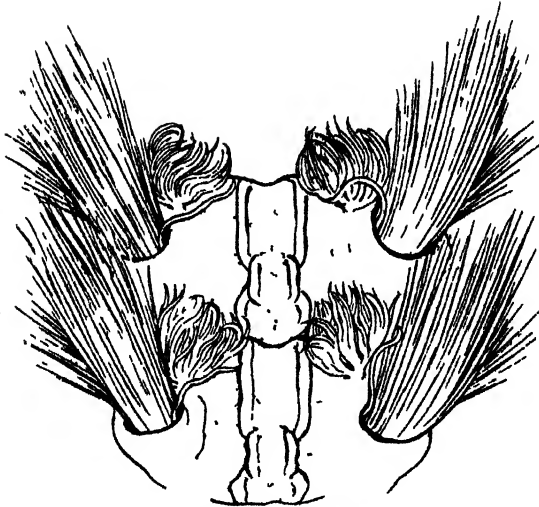
one-fifth as long as the caruncle and slightly shorter than the laterals. The gills, which are comparatively small, begin on the fifth segment, and the

FIG. 5.



*Notopygus Andrewsii*, sp. n.  
Caruncle.  $\times 11$ .

FIG. 6.



*Notopygus Andrewsii*, sp. n.  
Two anterior segments seen from the dorsal surface.  $\times 6$ .

dorsum has a curious arrangement of raised longitudinal ridges of integument (fig. 6), more conspicuous in the anterior than in the posterior segments,

and a complex furrowing. The dorsal cirrus has a large basal joint, and a flagelliform tip which reaches nearly to the tips of the chætæ. The branchial cirrus is small, scarcely larger than a single branchiole. There are 32 segments, and the anus is situated at the posterior edge of the 24th segment. The chætæ are not remarkable. They are large, yellow, and spread out fan-wise. Anteriorly the rami of the fork diverge at a wide angle, and the arms are backwardly reflexed. Posteriorly they become more bayonet-shaped, and the shorter ramus is reduced to a spur. Except that they are shorter, the ventral chætæ differ little from the dorsal. In the first two segments there are a few faint serrations on the long arm of the fork of the ventral chætæ. Otherwise the chætæ are completely smooth.

*Remarks* :—This species is very close to *Notopygus Gardineri*, Potts, but the caruncle is so different that the separation seems to be justified. Potts's species has a caruncle with an immensely high, compressed median crest and curious close-set ungrooved folds, neither of which characters is possessed by *N. Andrewsii*. Moreover, the dorsal chætæ of the anterior segments are serrated in Potts's and smooth in this species. The latter is, however, not a very satisfactory character. The complicated folding of the integument on the dorsum appears to be identical in both species.

*NOTOPYGUS HORSTI*, sp. n.

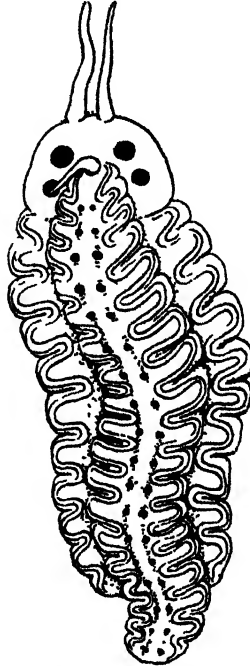
*Occurrence* :—"Franklin Shoal, Latitude 5° 53' S., Longitude 129° 19' E., N. Australia."

*Description* :—A single specimen, composed of 29 chætigers and measuring 18 mm. × 4 mm., excluding the feet. The prostomium is semi-rectangular, with two pairs of large black eyes, of which the anterior is slightly larger. The buccal region is cordiform, and the caruncle is attached far forward on the prostomium, between the anterior pair of eyes (fig. 7). The dorsum is marmorated with a dark purple pigment, which covers also the basal portion of the gills. The caruncle, which is composed of 18 folds, has a row of paired dark spots running along the top of the crest, and a dark line running along the edge of the folded lamellæ on either side. It reaches to the 6th chætiger and is narrower than is usual in *Notopygus*, and the lateral branches do not spread so far over the dorsum. The median tentacle is one-fifth as long as the caruncle. I am unable to compare its length with that of the laterals, since the latter have had their ends broken off. All the tentacles are pigmented. The first four segments are involved in the mouth and buccal region. The gills, which begin on the 5th chætiger, consist of a few slender filaments, coloured deep black on the lower portion of their anterior surfaces. The cirri are unpigmented, the dorsal having a large basal cirrophore and the branchial being very slender. The bifurcated chætæ are extremely long, plentiful, and formidable looking, and form a thick hedge all over the animal's back. The ventral chætæ are considerably stouter than the dorsal, and their denticulation can be observed only with difficulty and in a few cases. At



the best it appears to be a mere suggestion of toothings, but this may be due to the state of preservation. The anus forms a conspicuous papilla between the 22nd and 23rd segments. There are the usual two short anal cirri with a terminal knob.

FIG. 7.



*Notopygus Horsti*, sp. n.  
Caruncle.  $\times 34$ .

*Remarks* :—This species corresponds very closely with Horst's (1912, p. 31, pl. 9. figs. 13–16) description and figures of *Parachloeia marmorata*, but differs from it in being a true *Notopygus* with a dorsally-situated anus. There appears to be no other difference between these two genera than the situation of the anus. Horst does not actually mention the position of the anus in *Parachloeia*, but its terminal position may be inferred.

Chamberlin (1919, p. 25) in his key to the genera of the Amphinomidae classes *Parachloeia*, Horst, with those genera possessing a single dorsal cirrus. This is an error, as a reference to Horst's original description shows.

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## On the Cranial roofing-bones in the Dipnoi.

By EDWIN S. GOODRICH, F.R.S., F.L.S.

(Text-figures 1-7.)

[Read 8th January, 1925.]

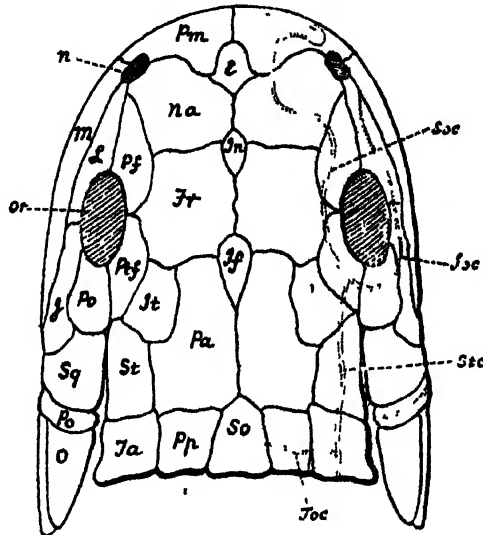
IN volume xxxv. of this Journal, Messrs. Watson and Gill published a valuable paper on the structure of Palæozoic Dipnoi in which many new observations are recorded and important additions made to our knowledge of these interesting fish. But in their figures of specimens and in their restorations they adopt an interpretation of the homology of the roofing-bones of the cranium with which, I think, few will agree. I refer more especially to their identification of the nasal, frontal, and parietal bones. Moreover, they give no detailed evidence and no arguments to justify the strange new view they put forward.

Until 1909, though several authors (Pander 5, Hancock and Atthey 3 & 4, Smith Woodward 9, and others) had made important observations on the cranial roof of the fossil Dipnoi, no serious attempt had been made to homologise the bones or to compare them in detail with those of the Teleostomes on the one hand and the living Dipnoi on the other. In the 'Treatise on Zoology' I made such an attempt, and published restorations of *Dipterus*, *Phaneropleuron*, and *Ctenodus*, naming the bones and tracing where possible their relation to the lateral-line system (1). For this system of canals is of great value in working out the homology of the cranial bones.

The course of the lateral-line canals is extraordinarily constant throughout the Pisces, far more constant, indeed, than the bones themselves, and is still retained in the primitive amphibious Tetrapods. In primitive fish with well-developed superficial bones the canals are deeply embedded in these bones, and so come to acquire a definite relation to some of them which is a valuable guide in comparison. It is true that some variation in the disposition of the canals does occur, that the relation of the canals to particular bones may not be absolutely constant, and that the problem of homology may be further complicated by the fact that a bone in one form may apparently be represented by two or more in another, owing to subdivision or fusion or the appearance of new elements; yet on the whole the fundamental plan is well preserved (see fig. 1). The problem is not an easy one, and certainty in many cases can hardly yet be reached. Having re-examined the material, including the fine collections at the British Museum, kindly put at my disposal by our former President, Sir A. Smith Woodward, and corrected the faulty restorations published fourteen years ago (1), I am prepared to defend the main conclusions put forward in the 'Treatise.'

In spite of the difficulties mentioned above, a general plan of the chief cranial bones can be made out to which conform not only the early fossil Teleostomes (Osteolepidoti, Palaeoniscoidei), the Chondrostei, the Polypterini, and the Holostei (Amioidoi, Lepidosteoidoi, Teleostei), but also the primitive Tetrapoda. Such a general plan is shown in fig. 1, and in it appear two frontals and two parietals surrounded by a series of smaller bones containing the lateral-line canals, excepting for a small portion of the supraorbital canal which may run in the frontal.

FIG. 1.



Primitive Fish.

*Lettering for Figures 1-6.*

Diagrams of the fundamental plan of the roofing-bones of the skull in Pisces and Tetrapoda (omitting the opercular bones).

*E*, ethmoid; *Fr*, frontal; *If*, interfrontal; *In*, internasal; *Ioc*, infraorbital canal; *It*, intertemporal; *J*, jugal; *L*, lacrimal; *m*, maxillary; *n*, nostril; *Na*, nasal; *O*, opercular; *Ob*, supraorbital; *Or*, orbit; *p*, marginal; *Pa*, parietal; *Pf*, prefrontal; *Ppf*, postfrontal; *Pp*, postparietal; *Po*, postorbital; *So*, dermal supraoccipital; *St*, supratemporal; *Soc*, supraorbital canal; *Stc*, supratemporal canal; *Sq*, squamosal; *Ta*, tabular; *Toc*, transverse occipital canal.

Now although the modern Dipnoi have departed very widely from this fundamental plan, there seems to be no great difficulty in tracing its main features in the more primitive fossils.

The lateral-line system on the head of the Dipnoi is essentially similar to that of the Teleostomes and Tetrapods; but, unfortunately, the canals retain their primitive position inside the bones only in the genera *Dipterus* and

*Phaneropleuron*; while in the other, and presumably more specialised genera, the bones sink below, leaving the canals in the skin. In the modern forms, indeed, all connection with the cranium is lost, and the canals lie in the thick layer of connective tissue between the skull and the secondarily developed scales on the head (1). Yet the canals still retain their original course in *Ceratodus*\* (fig. 7).

Comparing, now, *Dipterus platycephalus* with our fundamental plan, we seem clearly to recognize the frontals, the parietals, and the surrounding

FIG. 2.



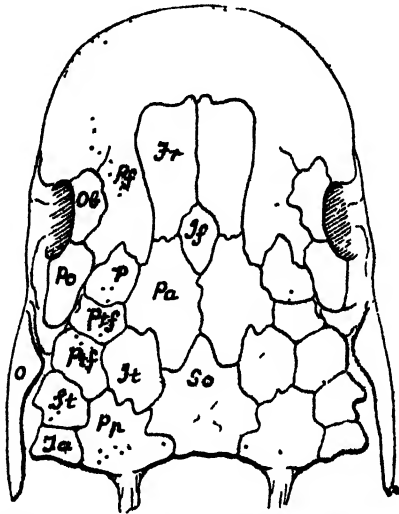
Photograph of *Dipterus platycephalus*. No. 5780 in the British Museum.

bones with the lateral-line canals (figs. 2 and 3). Watson and Gill, however, adopt an entirely different interpretation. In *Dipterus*, *Ctenodus*, and *Sagenodus* they call the large anterior bones (our frontals) the nasals, and the paired bones behind them the frontals, and are thus driven to the assumption that the parietals are represented by the posterior median occipital plate, though there is no evidence whatever that this plate is of paired origin. This surprising view ignores the fact that the anterior bones do not include the lateral-line canals (as they should if nasals), and are of

\* The exact course of these canals in *Ceratodus* never seems to have been figured, so I take this opportunity of publishing the results of a dissection recently made (fig. 7). The branch canals leading to the external pores (not shown in the figure) pass outward often through the large head-scales,

extraordinarily large size for nasals in an animal with the snout so little developed. They would also occupy an unusually posterior position extending about half-way over the orbit. Moreover, the bones in front of them in *Ctenodus*, which would seem to be naturally interpreted as nasals (fig. 5), comparable to those of other fish, have to be called by Watson and Gill the prenasals, for which name it is hard to find any justification. The so-called frontals of Watson and Gill are situated much farther back than the frontals of other fish, and occupy, indeed, just the position of parietals.

FIG. 3.

Restoration of the skull of *Dipterus platycephalus*

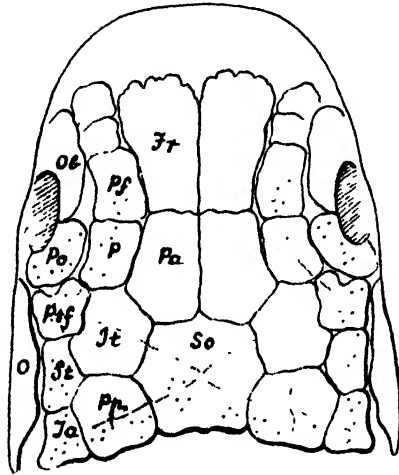
If we compare the general shape and proportions of the head of a Dipnoan with that of an Osteolepid (see 2, fig. 1 A), we see that in the Dipnoan the head is broader, the orbit farther back, and consequently the postorbital region much shorter, the cheek reduced, and the operculum relatively farther forward. We should expect to find, then, the frontals and parietals farther forward than in the Osteolepid. This is the very reverse of what occurs according to Watson and Gill.

In 1909 (1) I pointed out that, of all known living and extinct Dipnoi, *Scaumenacia* (*Phaneropleuron*) is the genus which most nearly approaches the usual type in the form of its roofing skull-bones (fig. 4). In this Dipnoan the frontals and parietals are large bones, not separated in the middle line by a median element. Here the general relationships of the surrounding bones and lateral-line canals clearly indicate that we have to deal not with nasals and frontals but with frontals and parietals.

Whether the absence of a median interfrontal in *Scaumenacia* is primitive or secondary cannot yet be determined. We do not yet know what was the structure of the ancestral Dipnoan; but it is nevertheless recognized

that one of the characteristic features of the group is the increasing development of median bones and accompanying reduction and specialization of the paired elements, until in modern forms the median bones remain as the chief elements covering the brain-case (compare figs. 3, 5, 6, and 7). These median bones are a large dermal supraoccipital (parietal of Watson and Gill), a smaller interfrontal, an internasal, and a quite anterior median ethmoid. The latter (internasal of Watson and Gill) is rarely found as a separate bone in Dipnoi; it may grow into the large anterior plate in living genera (fig. 7), which, however, may also include the internasal and interfrontal. The

FIG. 4.



Restoration of the skull of *Scaumenacia* (*Phaneropleuron*) *curta*.

posterior median supraoccipital seems undoubtedly to be the same bone as the very similar dermal supraoccipital present in Osteolepids and certain other primitive Teleostomes (*Acipenser*). It contains the transverse occipital or suprtemporal canal, or at least its external pores, and is marked by a characteristic X-shaped groove apparently for pit organs (figs. 2, 3, and 4). As already remarked, it shows no evidence of being of paired nature, and has a single median centre of growth. This plate, and possibly also the other median plates, may perhaps belong to the row of scales running along the trunk in front of the median dorsal fin.

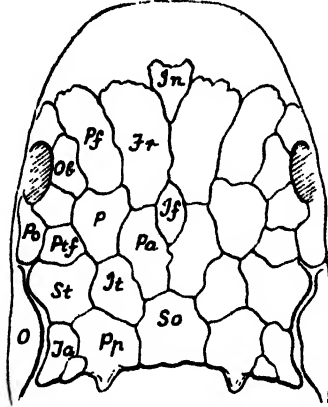
Prof. Watson has kindly shown me some specimens of *Dipterus valenciennesii* in which there is some evidence of the existence of a posterior transverse row of plates bearing the occipital lateral-line canal\*. If this interpretation is correct (the evidence is by no means convincing), it would seem that the single row in *D. platycephalus* (tabulare, postparietal, and

\* I have since found that Prof. W. Patten figures a posterior median plate behind the large supraoccipital in *Scaumenacia*, in his book on the 'Evolution of Vertebrates.' [7 May, 1925.]



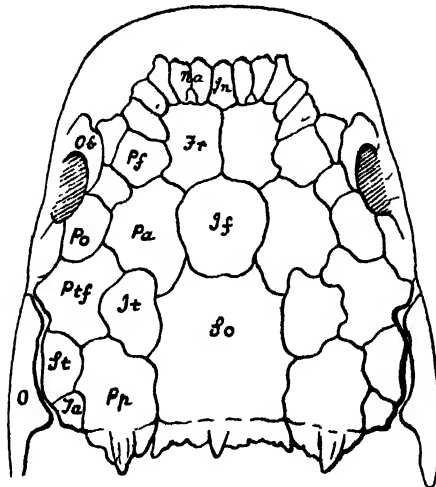
median occipital) is represented by two rows in the earlier form *D. calenciennesii*. And if this is the more primitive condition, the single row found in all other Dipnoi might be brought about by fusion. Only the discovery of more perfect fossils can enable us to settle this difficult point. In the meantime my main contention remains unaffected.

FIG. 5.



Restoration of the skull of *Xenodus*. Partly from Watson and Gill.

FIG. 6.

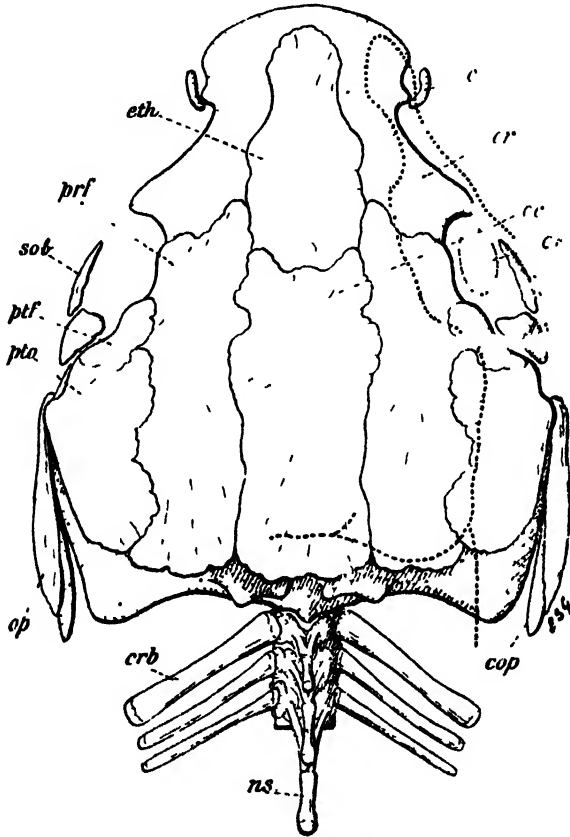


Restoration of the skull of *Sagenodus*. Partly from Watson and Gill.

Of the paired elements, the most anterior, generally fused in front with neighbouring bones, may represent the nasals (fig. 6). Behind them, adjoining the frontals and enclosing the supraorbital canal, are marginal plates, two or more on each side. Doubtless these represent the pre- and postfrontals of other forms; but in this interorbital region the head of the

Dipnoi is peculiar in that the frontals do not include the supraorbital canals, as is usual among the Teleostomes, for instance in *Palæoniscus* (Traquair, 7). Other Palæoniscoids show intermediate conditions, as in *Arelia*, where the canal-pores are between the frontals and the marginals (Stensiö, 6).

FIG. 7.

Skull of *Ceratodus*.

Cartilage is dotted. The course of the lateral-line canals is indicated by a dotted line on the right side.

*c*, labial cartilage; *cop*, opercular cartilage; *cr*, cartilaginous cranium; *crb*, cranial rib; *eth*, ethmoid bone, possibly includes internasal and interfrontal; *ns*, neural spine; *oc*, dermal supraoccipital bone; *op*, operculum; *or*, orbit; *prf*, lateral plate = "pre-frontal," possibly includes parietal, intertemporal, and postparietal of *Sagenodus*; *ptf*, postfrontal; *pta*, pterotic = supratemporal; *sob*, suborbital.

The difficulties increase when we try to determine the homologies of the bones at the side of the cranial roof behind the orbit. Here is found a group of five bones, two more median and three lateral. If the former represent the intertemporal and tabulare of other forms, as held by Watson and Gill, we should, on comparing them with *Osteolepis*, expect them to

contain the longitudinal canals, which, as far as I can ascertain, they do not\*.

I would suggest that the intertemporal has been correctly identified by Watson and Gill, but that it has shifted inwards in the Dipnoi in correlation with the broadening of this part of the roof†. The intertemporal occupies the same position in the Stegocephalia.

The three outer bones would then represent the postfrontal, supratemporal, and tabulare of other fish harbouring the longitudinal canal as usual; but which of the two bones at the posterior edge of the skull is really the tabulare it is difficult to say. For the present it would perhaps be better to call the outer corner bone the tabulare and the inner one the postparietal, as in the Stegocephalia. The bone Watson and Gill call 'squamosal' would then be the supratemporal (pteryotic), and this conclusion seems more natural, since in other forms the squamosal lies on the lateral cheek and forms no part of the roof, nor does it enclose the longitudinal lateral-line canal.

It may readily be admitted that the homology of many of these bones is doubtful, and that more research is necessary before it can be established. Indeed, only the discovery of intermediate forms between the Dipnoi and the Osteolepids or the Tetrapods can bring certainty. Nevertheless, it would seem that the interpretation here put forward is more in accordance with what we know of the structure of other fish and of primitive tetrapods than that proposed by Messrs. Watson and Gill.

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\* Unfortunately the material at my disposal has not enabled me to see the actual canal in this region, but only to infer its course from the disposition of the pores on the surface. A group of pores occurs on the so-called intertemporal (W. and G.); nevertheless, there can be little doubt that the canal itself runs in the three outer bones along which the pores mark a continuous track.

† If Watson and Gill are, after all, correct in their naming of the frontal, then, surely, the so-called intertemporal must be the parietal displaced outwards by the large supra-occipital.

The Morphology of the Carboniferous Scorpion *Eobuthus*, Fritsch. By  
LEONARD J. WILLS, M.A., Ph.D., F.G.S. (Communicated by Dr. W. T.  
CALMAN, F.R.S., Sec.L.S.)

(PLATE 3 and 3 Text-figures.)

[Read 4th December, 1924.]

THE specimen that has provided the material for this paper was found by the author on an old pit-bank at Preesgweene near Chirk, at the south end of the Ruabon Coalfield. The exact horizon in the measures from which it was derived is unknown, but it is believed to be somewhere about that of the Main Coal. The microscopic preparations are in the collection of H.M. Geological Survey, Jermyn Street, London.

The remains of the scorpion are preserved in chitin that still retains a modicum of flexibility and toughness. Thanks to this, it has been possible, by means of the method devised when investigating the Triassic scorpions from Bromsgrove, to remove a good deal of the shale in which it lay, though in doing so and in mounting in balsam the specimen has been considerably broken\*. This is of no great consequence, as, had it been left intact in the shale, its fragmentary and crushed state would have prevented its detailed investigation; in fact, it is improbable that it would have been possible to identify the genus.

The head-shield and the four anterior appendages of the prosoma, and the entire tail are missing; but parts of the dorsal and ventral plates of the mesosoma, the sternum and genital operculum, the coxal segments of the third and fourth legs, the protarsus and tarsus of one leg, and most of the two halves of the pecten are available for microscopic examination, and reveal what is, for a fossil, an almost incredible wealth of detail. It is the purpose of this paper to describe these minutiae, in the hope that they may throw light on the morphology, and so, indirectly, on the habitat and relationships of these early members of the ancient race of the Scorpions.

The more or less oval shape of the sternum, the paired genital operculum, against the sides of which abut the coxæ of the fourth leg, and the overlapping lobate sternites, indicate that the animal belonged to Pocock's group the *Lobosterni*†. These characters agree sufficiently well with the diagnosis

\* For method see Proc. Geol. Assoc. vol. xxi. 1910, p. 303.

† R. I. Pocock, 'Monogr. of the Terrestrial Carboniferous Arachnida of Great Britain.' Palaeontographical Society, 1911, p. 10.

of Fritsch's genus *Eobuthus*\* for us to apply this name, though the tarsal segment of the leg carries a claw unlike any so far described from either fossil or living scorpions.

Despite the wonderful preservation of individual parts, there are many difficulties in interpreting the fossil remains of a segmented creature, like a scorpion, on account of its liability to fall to pieces before fossilization. These inherent difficulties are increased by the damage done in extracting the fragments from the rock.

As a rule, each segment carries with it more or less of the thin inter-segmental skin connecting it to its neighbours. This appears in the fossil as a fringing border outside the limits of the segment proper, which is usually delimited either by a band of thicker chitin or by a row of blunt spines. I propose to apply the term "*doublure*" to this fringe of connecting skin. Very frequently the doublure is bent back upon the segment proper if the segment was one that overlapped its neighbour. Thus on the overlapping sternites (p. 93) the anterior doublure is a forward continuation of the segment, but the posterior doublure is folded back so that in the fossil it overlies the segment as seen in dorsal aspect. Similarly, in a fossil we cannot expect to see all the setæ that once clothed many parts of the scorpion. It is, in fact, remarkable that any at all are preserved. In the descriptions the former presence of movable sensory setæ is assumed where the test shows the little circles of very thin tissue that I speak of as "*hair-facets*." Occasionally hairs can be seen still attached at these points both in this fossil and in the Triassic *Mesophonus*†.

#### DESCRIPTION OF THE SEVERAL PARTS.

A. *Dorsal tergites*.—Parts of three and possibly four tergites are preserved. They are composed of rather thick chitin (Pl. 3. fig. 17), covered with a fine reticulate pattern. The length of the tergites increases posteriorly. Each segment is defined behind by a row of stout posteriorly-directed blunt spines, and in front by a narrow line of thicker chitin; outside these limits is a doublure of thinner chitin, bearing small sensory setæ both anteriorly and laterally. At its postero-lateral corner blunt spines occur. The posterior doublure is infolded, allowing the segment to articulate by overlap with the next behind. The tergites were thickly covered by movable setæ, a fact indicated by numerous hair-facets of two sizes (Pl. 3. fig. 17 and text-fig. 1 B). The following are the dimensions in millimetres of the three tergites, exclusive of the doublure:—

	No. 1.	No. 2.	No. 3.
Length .....	2.2	2.4	3.0 mm.
Breadth .....	—	15.0	— „

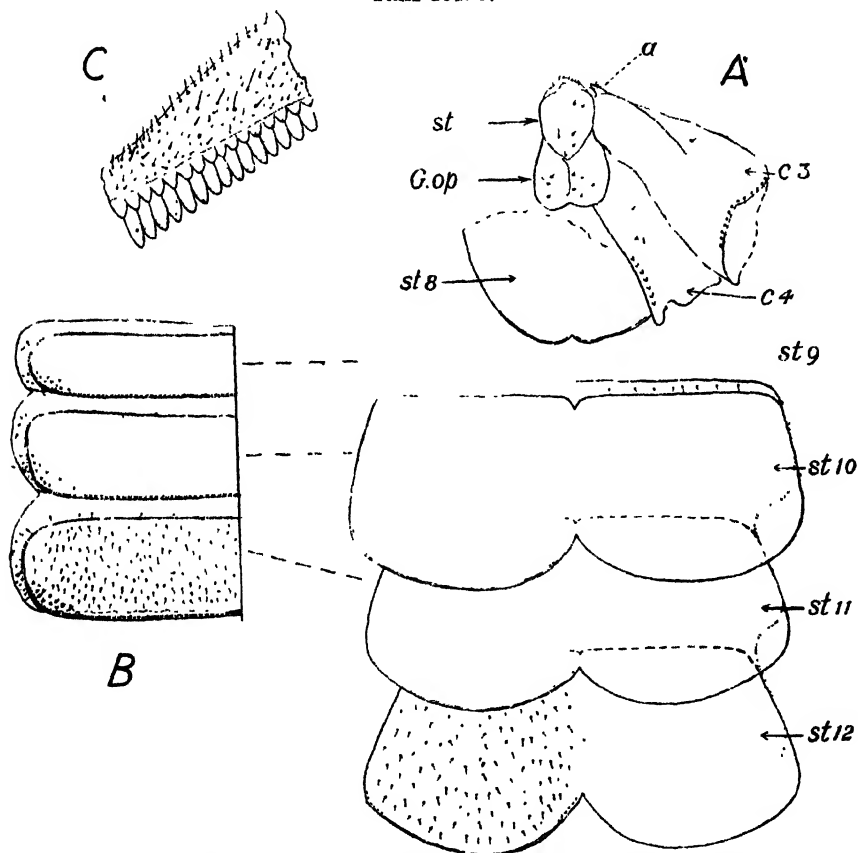
\* A. Fritsch, 'Paläozoischer Arachniden,' Prag, 1904, p. 474.

† Wills, Proc. Geol. Assoc. vol. xxi. 1910, p. 322.

B. *The ventral surface.*

The *sternum* of the prosoma, the paired *genital operculum*, and the *coxa* joints of the third and fourth legs are preserved together. Pl. 3. fig. 3 shows the ventral aspect of the specimen (see also text-fig. 1 A). The coxæ of the left side (right in the photo) are in their natural position, and are indicated as *c* 3 and *c* 4, but those of the right side are displaced and folded,

TEXT-FIG. 1.

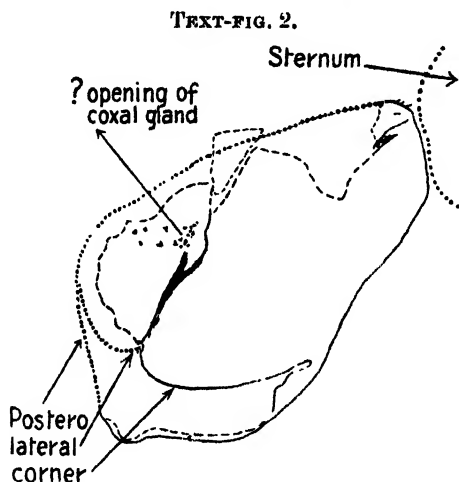


Outline reconstructions: A, ventral surface; B, three tergites, left halves; C, part of pecten.

so that part of right coxa 4 and most of right coxa 3 come to lie on the back of the specimen, where they can however be examined.

The *sternum* of the prosoma is hexagonal in outline, and almost devoid of hairs and ornament on its surface. Length 3 mm., breadth 2 m. Its anterior edges are continued dorsally by several folds of thin skin, that pass into a dorsally-directed sheet of chitin that still carries very thick-set, slender sensory hairs, and it is probable that it served to box in the posterior part of the mouth-groove.

The *third coxa* of the left side is still in place in the specimen figured (Pl. 3. fig. 3, C 3). It abuts against the sides of the sternum, and seems to lie dorsally to it. At the anterior end it appears to carry an unjointed epicoxite (*a*) thickly covered with small sensory setæ similar to those on the sternum. The epicoxites appear to have formed the postero-lateral sides of the mouth-groove. The dorsal side of this coxa is, in part, exposed on the reverse of the specimen along with the crushed and displaced right coxa 3. On the latter, as shown in text-fig. 2, there is a small group of minute blunt spines, surrounding a depression still filled with shale. A groove runs distally from this depression, but it is difficult to say whether this is an original feature or due to crushing. Such spines are usually found in places where additional support for the integument was needed. It is just possible that in this case



Dorso-lateral view of right coxa 3. Broken lines indicate fractured edges, peck-lines reconstruct the outline.

they functioned to protect the opening of the coxal gland, which is situated on this segment in recent scorpions. The opening, if present, is concealed by a small piece of shale. A similar but less definitely-displayed group of spines occurs on the dorsal surface of the left coxa 3. Taking all the evidence into consideration, it seems probable that this group of spines lies towards the outer edge of the coxa on the dorsal surface and about a third of the length of the coxa in front of the distal end of the segment. Their connection with the coxal gland is doubtful, especially as their position is different from that at which the gland opens on *Scorpio*.

The *fourth coxa* of the left side is seen to abut against the side of the genital operculum (Pl. 3. fig. 3, C 4, and text-fig. 1 A). It appears to pass dorsally over the lateral edges of the operculum. The inner edge of the coxa carries posteriorly, on the ventral surface, a row of strong, blunt, immovable spines.

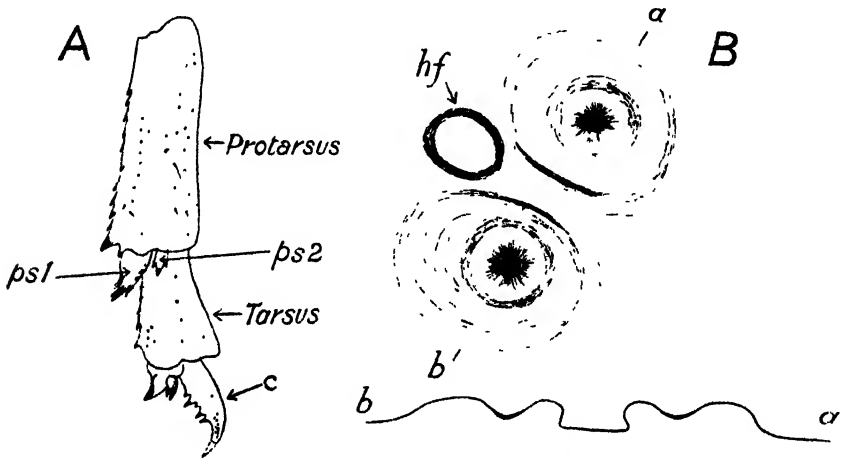
The abutment of coxa 4 against the sides of the genital operculum is regarded as a feature characteristic of the class Lobosterni, as defined by Pocock (*op. cit.* p. 10).

Among the *disjecta membra* are the *protarsus* and *tarsus* of one leg, which are of considerable interest (Pl. 3. fig. 1 and text-fig. 3 A).

The protarsus was covered by small sensory setæ, and has a row of strong immovable spines. It carries a large pedal spur (*ps 1*) set with small sharp spines and long sensory bristles. A smaller movable trifid spur is seen to one side of the large spur (*ps 2*). Among recent scorpions the family Buthidæ is characterized by having two pedal spurs\*.

The *tarsus* had fewer sensory hairs, and its spines are less strong than those of the protarsus. It carries a large toothed claw (*c*), near the distal end of

TEXT-FIG. 3.



A. Protarsus and tarsus. B. Tubercles and hair-facet on a leg-segment;  
*hf*, hair-facet; *a-b*, section.

which was a bunch of small sensory setæ, that are represented by hair-facets. One seta is still in place. At the proximal end of the claw is a structure which may be the basal part of the claw or a movable spur. Two minute apparently-movable spurs lie at the side of it, but both are attached to the same surface. Whether a similar pair occurs on the reverse cannot be determined because of adherent shale. The claw and spurs have been displaced laterally, as seen in the photograph (Pl. 3. fig. 1). They are in approximately the natural position in text-fig. 3 A.

No such toothed claw has ever been described from among fossil scorpions, which have always been illustrated with simple claws as in the recent forms. There is no evidence in the specimen that a second claw was present, as is the case in recent forms.

\* R. I. Pocock, *Ann. & Mag. Nat. Hist.* ser. 6, vol. xii. 1893, p. 303.



The chitin of the protarsus and tarsus is stout, and displays a markedly reticulate structure.

Among the Preesgweene preparations there are several fragments of other leg segments which have a similar structure. They are mostly long and narrow as in *Eobuthus rakornicensis*, Fritsch. One segment, broken across, is figured on Pl. 3. fig. 15.

One of these fragments bears depressed knob-shaped tubercles, each with a central thickening of the chitin. In some cases this central part forms a pit (text-fig. 3 B and Pl. 3. fig. 18). The tubercles vary in size, but are usually considerably larger than the hair-facets (*hf*). Most of them are arranged in a row parallel to the length of the segment, but others are scattered. Their function is problematical.

Another singular fragment may possibly be a portion of one of the coxal segments of legs 1 or 2. It carries a thin skin on one side. This has been displaced; and Pl. 3. fig. 8 shows it to be covered thickly with stout, short spinules, which differ from the setæ found elsewhere in these specimens in being obviously hollow. In the other movable setæ there is a trace of a cavity at the proximal end, but these spinules have an appearance of being hollow out-growths of the skin. They were possibly movable.

#### 1st Mesosomatic Segment.

The genital operculum is divided into two halves by a median groove or fold that extends from the front very nearly to the posterior margin (Pl. 3. fig. 3, *g.o.* and text-fig. 1 A, *G.op.*). The operculum carries a few scattered hairs. Its edges, as with the sternum, are in-turned, but to what extent cannot be ascertained. The posterior end of the sternum lies between the anterior sides of the two lobes of the genital operculum. It cannot be determined whether the operculum was immovably fixed to the sternum, but it was probably so, as the skin of the two sclerites is continuous, and the inter-segmental chitin shows little, if any, signs of being thinner here than elsewhere.

#### 2nd Mesosomatic Segment.

According to Pocock the pectines of *Eobuthus* are carried by a sternal plate with indications of a median notch on the posterior side (*op. cit.* p. 14 and text-fig. 1). This plate, as figured by Pocock, is about the same size as one of the lobes of the respiratory sternites. A fragment (Pl. 3. fig. 11) from the Preesgweene specimen agrees in these characters. It has a broad in-turned doublure that makes the posterior part double. The in-turned flap carries minute immovable spines, while the outside of the sclerite is covered with small hair-facets. The line of thicker chitin and band of ornament bounding the segment behind is notched at (*a*). In these particulars it agrees with the structure of the lobed sternites. It is possible that the sclerite is the sternum of the pectines.

The *Pectines*.—These appendages are modelled on exactly the same plan as in a recent scorpion, such as *Buthus*, as illustrated (Pl. 3. fig. 5). Here we see the rhachis carrying large sensory setæ and bearing a row of triangular fulera, each with its quota of setæ. Alternating with these are the teeth of the "comb," thickly covered with diminutive "goblet-like" organs\*. In the fossil it has not been possible to elucidate the full characteristics of the rhachis of the pecten, but it is fairly broad and made of thin chitin that is covered with long sensory setæ, some of which are still attached (Pl. 3. fig. 7). The rhachis carries small triangular fulera. Some of the fulera bore two or three sensory setæ (represented by large hair-pits) at their tips. In the specimen figured (Pl. 3. fig. 7) the fulera point in the wrong direction, having been bent over during entombment, but their true arrangement is seen in Pl. 3. figs. 4 & 6 and text-fig. 1 C. Alternating with the fulera are the teeth of the comb. The teeth are covered by minute pits that appear to have one or sometimes two papillæ within them (Pl. 3. figs. 4 & 10). They are, in fact, indistinguishable from the "goblet-like organs" on the comb of the recent scorpion.

On Pl. 3. fig. 4 a single tooth, a fulcrum, and piece of the rhachis is reproduced for comparison with the corresponding parts of the recent animal (fig. 5).

### 3rd Mesosomatic Segment †.

The sternite of the 3rd mesosomatic segment, if preserved at all, is seen in the fragment labelled IX on Pl. 3. fig. 13, which, however, displays nothing definite.

### 4th, 5th, and 6th Mesosomatic Segments.

Parts of three lobate sternites are preserved. They probably belong to the 4th, 5th, and 6th mesosomatic segments (*cf.* Pocock, *op. cit.* p. 15). One of these (sternite XI, Pl. 3. fig. 13 and text-fig. 1 Δ) lies on the reverse of the specimen that displays the tergites. The maximum length of the sternite from back to front is rather more than twice that of the second tergite, in a line with which it now lies; but its minimum length (at the notch) is only one-third greater. The segment (apart from the doublure) is defined anteriorly by a narrow line of thicker skin as in the tergites, but the line has an anterior median notch (*an*) pointing backwards towards the larger posterior notch (*pn*) that separates the two lobes. Round the lobes is a band of very depressed blunt spines somewhat similar to but weaker than those on the tergites. The thin skin of the sternite is somewhat crumpled as if it had not been a flat segment, but adapted perhaps to allow of the distension of the abdomen.

\* So called by Gaskell. They are small sensory papillæ, each situated in a minute pit.

† On Pl. 3. figs. 11 to 13 illustrating the sternites are all at the same magnification.

In Pl. 3. figs. 2 & 12, which are photographs of the detached parts of sternite X, of which a portion is in place in the specimen shown in fig. 13, X, it is seen that the lobate portion is made of two thicknesses of chitin, the in-turned posterior doublure constituting a thin flap on the inner side, which extends forward to about in a line with the apex of the posterior notch. This shows that the segment overlapped the one behind by this amount, the overlapping part representing the difference in length between the sternite and corresponding tergite. The numerous hair-facets on the exterior of the sternite, clearly seen in Pl. 3. fig. 12, indicate that it was thickly covered by small movable setæ, some of which are still attached (text-fig. 1 A and Pl. 3. fig. 16). The flap, on the other hand, is covered by minute immovable spines, pointing posteriorly (Pl. 3. fig. 16).

A careful examination has shown that there were no stigmata either on the exterior of the segment or on the flap. This can be verified on the large photograph (Pl. 3. fig. 2). At the point (a) (fig. 2) there is a piece of tenuous crumpled skin with very minute hairs (figs. 9 & 16). This skin probably represents the ventral body-wall where it is overlapped by the lobe of the segment, and no doubt passed backwards into the anterior doublure of the next sternite\*. If this view be correct, the minute hairs gave place posteriorly to larger ones, which are evidenced by the very numerous small hair-facets (with occasional setæ attached) on the anterior doublure of the sternites. These can just be discerned in Pl. 3. figs. 2 & 12.

The third lobate segment XII is illustrated in fig. 13, XII, but shows nothing more than those already described.

The features just reviewed confirm the suggestion put forward by Pocock (*op. cit.* pp. 14, 15) that the lobes covered and protected the breathing apparatus of *Eobuthus*. This organ he designated as the respiratory lamellæ. The evidence of the *Preesgweena* specimen suggests one of two things, either that the thin hairy skin of the ventral body-wall formed the respiratory surface; or that the lamellæ were carried by the body-wall near its junction with the in-turned flap of the lobe, and the hairs acted perhaps as filters. In the latter case the hairs may be compared with those found at the sides of the stigmata in the Triassic *Mesophonus*†. Though possible, it seems unlikely that the thin hairy skin is the remains of the chitinous covering of respiratory lamellæ. Mr. Eastham kindly made a preparation for me of the

\* Since arriving at the above conclusions. I find that Brauer figures and describes a very similar arrangement in the embryonic scorpion. He is of opinion that the lung-books of the adult are the morphological equivalent of outgrowths which originate on the appendage-traces of mesosomatic segments of the embryo, and which he regards as gill-rudiments. His evidence supports Kingsley's theory of the origin of the lung-books.

A. Brauer, "Beiträge zur Kenntnis der Entwicklungsgeschichte des Skorpions," *Zeit. wiss. Zool.*, Bd. lix. 1895, pp. 412-416 and fig. 15.

† L. J. Wills, *op. cit.* pp. 308, 313.

lamellæ of the lung-book of a scorpion. It is fringed by minute hairs that do not resemble those under description. Lankester mentions that the lamellæ of the lung-book are covered with reticulate thickenings and hairs.

The evidence in the specimen is insufficient to decide what form the breathing apparatus took, but the absence of stigmata seems to rule out the possibility of lung-books. If *Eobothus* was a terrestrial animal, the lobes appear inadequate to protect the breathing apparatus; and it seems more likely that the animal was aquatic and breathed by gills lying above the lobes.

The lobed ventral sclerite with its median anterior and posterior notches may, on this interpretation, be regarded as a pair of fused appendages rather than as a body-sternite\*. Pocock has already pointed out the similarity of the lobed segments to the gill-bearing appendages of *Limulus* (*op. cit.* p. 15). Their structure recalls the arrangement of the paired laminate appendages of Eurypterids, which at first sight might be taken for sternites. In *Eurypterus*† traces of the breathing apparatus can be detected, but there is still some doubt whether the gills were borne on the body-skin or on the inner flap of the appendage. Laurie has shown that in *Slimonia* lobed appendages concealed the gills‡. For these reasons it seems possible that *Eobothus* and the other Lobosterni breathed by gills despite their general similarity to the true Scorpions in other respects. They would, on this view, be aquatic. The same assumption has been made in the case of the Silurian Orthosterni, *Palæophonus* and *Proscorpius*, where the unlobed sternal plates have been interpreted as gill-bearing appendages comparable to those in *Eurypterus*. It is possible that those Carboniferous Orthosterni which do not exhibit stigmata had the same type of respiratory organs and were also aquatic (see p. 96).

It is easy to imagine the evolution of lung-books of the terrestrial scorpions from the protected gills of a creature like *Eobothus* or *Palæophonus*, if we assume that, except over two small stretches (the future stigmata), the posterior edges of the gill-bearing appendages become fused to the body-skin§. This would result in the gills being effectively boxed in. Outwardly the appendages would then be indistinguishable from sternites, and the thin skin or doublure connecting them would carry the stigmata. The latter might easily during later stages of evolution migrate from this position to that which they occupy in the present-day Scorpions.

\* Note, however, the close structural resemblance between the sternum of the pecten and the respiratory sternites, see p. 92.

† G. Holm, "Ueber die Organisation des *Eurypterus fischeri*, Eichw.," *Mém. Acad. Imp. Sci. St. Pétersbourg*, ser. 8, vol. viii. 1898, pp. 36-38 and Taf. 6, fig. 5.

‡ M. Laurie, *Trans. Roy. Soc. Edinburgh*, vol. xxxvii. 1893, p. 514.

§ As first suggested by J. MacLeod, *Archiv. Biol.* vol. v. 1884, pp. 1-34.

The arrangement in the Triassic *Mesophonus*\* appears to agree in general with such an hypothetical intermediate form. Here the stigmata of the lung-books are found on the in-turned postero-lateral doublure of the sternites. For this reason they are invisible if the specimen is adherent to the rock. Such an arrangement of concealed stigmata must be borne in mind when interpreting the Silurian and Carboniferous Orthosterni in which stigmata are not visible: for it is conceivable that they also had concealed stigmata, and were not aquatic as suggested above.

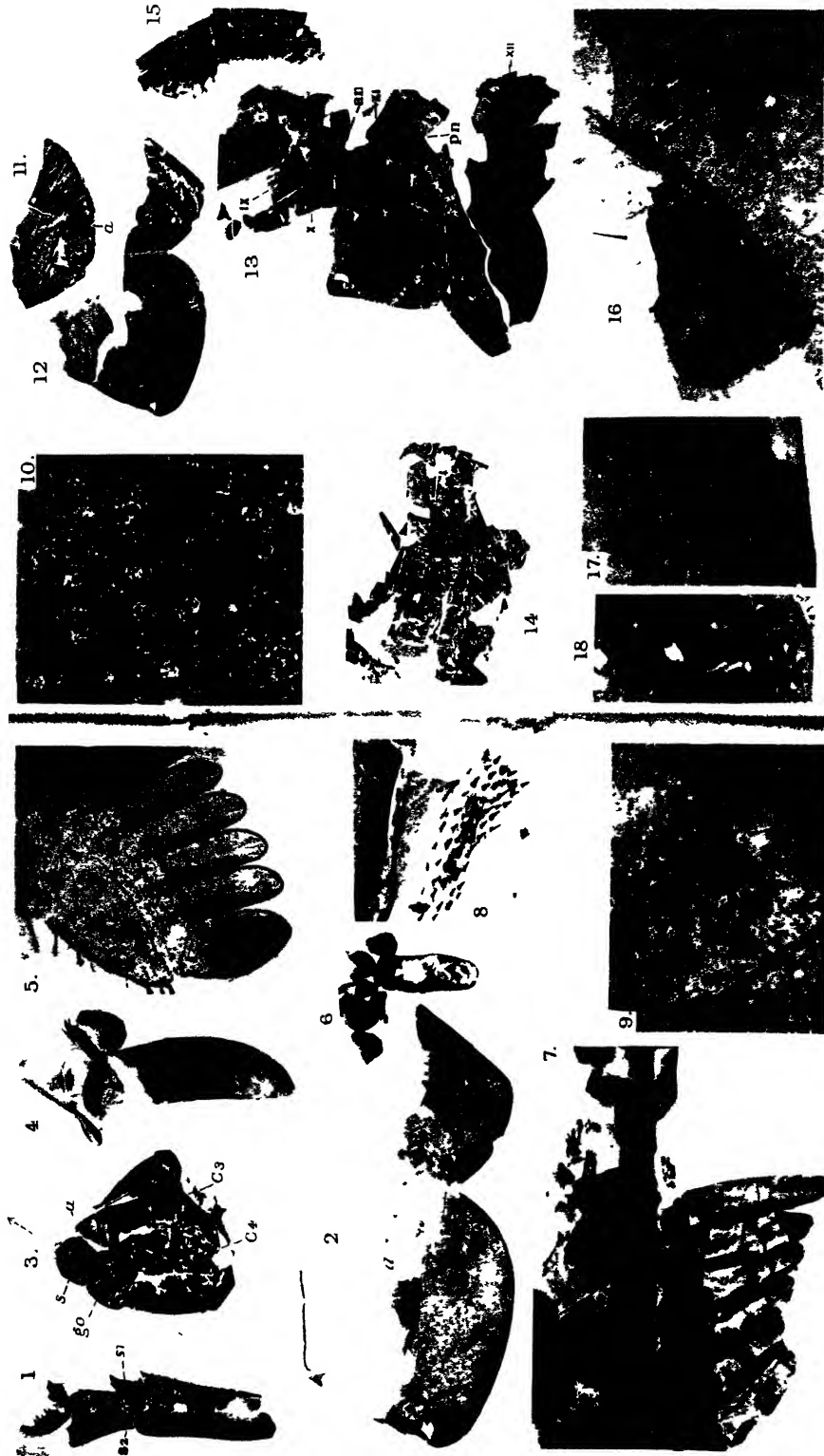
Pocock emphasises the importance of the shape of the sternal plates in that he uses this feature to group the Carboniferous Scorpions into the two sub-orders—the Lobosterni and the Orthosterni. Of the latter, *Palaeophonus*, on the usually-accepted interpretation of its sternal plates as gill-bearing appendages, has exactly the same breathing apparatus as *Eurypterus*. If *Eobuthus* be aquatic, it can with equal justice be compared with the Merostome *Slimonia*. Assuming a genetic connection between the Scorpions and the Merostomes, it appears possible that *Palaeophonus* and its descendants, the Orthosterni, may have evolved not directly from *Eurypterus*, but from a creature that was ancestral to both *Eurypterus* and those scorpions, while an analogous co-lateral relationship between *Slimonia* and the Lobosterni is equally admissible. If, therefore, the Orthosterni and Lobosterni are descended from different primitive Merostome stocks, the acquisition of the pecten has taken place by parallel development in two distinct lineages.

In contrast to the archaic arrangement of the respiratory organs, it is remarkable how closely the pecten of *Eobuthus* agrees in minutest details with that of the present-day Scorpion. Had we not known that the comb was already evolved by Silurian times, in the aquatic *Palaeophonus* and *Proscorpius*, the presence of this organ, unknown in any class of Arthropods other than the essentially terrestrial group of the Scorpions, would have convinced us that *Eobuthus* was a land animal. But with these data in view, the comb cannot be held to preclude the possibility that this creature was aquatic.

My sincere thanks are tendered to Mr. L. Eastham and Mr. Stanley Hirst for help and criticisms, and to Dr. Calman for acting as sponsor to this paper.

\* Wills, *op. cit.* p. 308.





Black, coll

THE CARBONIFEROUS SCORPION EOBUTHUS, FRITSCH





## EXPLANATION OF PLATE 3.

All the figures except fig. 5 illustrate parts of *Eobuthus* sp. from the Coal Measures of Preesgweene, near Chirk, N. Wales.

Except where stated to the contrary, the photographs have been made by using a combination of reflected and transmitted light.

- Fig. 1. Protarsus and tarsus of a leg, with toothed claw. S1 and S2, pedal spurs.  $\times 6$ .  
 Fig. 2. Sternite of 4th mesosomatic segment. *a*, folded body-skin with hairs. Transmitted light.  $\times 6$ .  
 Fig. 3. *s*, sternum of prosoma, *go*, genital operculum; C3, C4, coxa of 3rd and 4th legs; *a*, ? epicovite. The dotted line indicates the position of the median plane.  $\times 4$ .  
 Fig. 4. Part of rhachis, a fulcrum, and one tooth of the pecten. Shows the crowded "goblet-like organs." Transmitted light.  $\times 34$ .  
 Fig. 5. Distal end of pecten of a recent scorpion. Transmitted light.  $\times$  about 34.  
 Fig. 6. Part of pecten, showing five fulera and one tooth of the comb in their natural positions. (Chiefly reflected light.  $\times$  about 15.  
 Fig. 7. Part of the pecten, showing sensory setae and hair-facets on the rhachis, the fulera reversed, and six teeth which exhibit in places the crowded "goblet-like organs."  $\times$  about 24.  
 Fig. 8. ? Part of a coxal segment of a leg; shows hollow spinules. Transmitted light.  $\times$  about 30.  
 Fig. 9. Fine hairs on the skin above the overlapping lobe of sternite of 4th mesosomatic segment (*cf.* fig. 2 *a*). Transmitted light.  $\times 200$ .  
 Fig. 10. The "goblet-like organs" on the tooth of the pecten. Transmitted light.  $\times 600$ .  
 Fig. 11. ? Sternum of the pecten. *a*, the posterior notch.  $\times 4$ .  
 Fig. 12. Part of the sternite of the 4th mesosomatic segment. The anterior broken part fits on to the piece shown at X on fig. 13. The punctate appearance is produced by numerous hair-facets.  $\times 4$ .  
 Fig. 13. Sternites IX, X, XI, XII of the 3rd, 4th, 5th, and 6th mesosomatic segments. *an*, anterior notch; *pn*, posterior notch.  $\times 4$ .  
 Fig. 14. Three tergites.  $\times 2\frac{1}{2}$ .  
 Fig. 15. A segment of a leg.  $\times 4$ .  
 Fig. 16. Part of the 4th mesosomatic sternite (*cf.* figs. 2 & 12). The large sensory seta is on the outer surface of the sternite; a similar seta was attached at each hair-facet. The small V-shaped spines are on the in-turned flap; the dark part covered with fine hairs is the body-skin (*cf.* fig. 2 *a*). The whole is much thinner than the tergite (fig. 17), and does not show the reticulate structure.  $\times$  about 30.  
 Fig. 17. Part of a tergite, showing the reticulate structure of the skin, large and small hair-facets, and a few blunt spines. Transmitted light.  $\times 26$ .  
 Fig. 18. Knob-like tubercles on a leg-segment; the smaller circles are hair-facets. Transmitted light.  $\times 70$ .



On Seriation and Asymmetry in the Cephalopod Radula. By G. C. ROBSON,  
M.A. (Communicated by Dr. W. T. CALMAN, F.R.S., Sec.L.S.)

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(With 3 Text-figures.)

[Read 5th March, 1925.]

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1. INTRODUCTION.

THE members of the Cephalopod family Octopodidae are divisible into two groups of unknown systematic value according to the structure of the median tooth of the radula, which may have a single large cusp or a large median cusp accompanied by smaller lateral ones.

Several authors who have described the radula of species belonging to the second group have figured a remarkable arrangement of the lateral cusps of the median tooth. The first person to comment on this arrangement appears to be Naef (1923), whose remarks freely translated we may present as an introduction to this subject.

"The radula [of the Octopodidae] exhibits characteristic traits which plainly tend to resemble those of the Ctenoglossa (Amphitretidae and Eledonellidae). This is especially true of the form of the teeth of the middle row. In this case the teeth are multicuspid and possess, in addition to a normal and regularly developed median cusp, two or three accessory cusps on each side. The latter are asymmetrically arranged, and are never the same in the successive teeth of a series. After a number of teeth [of a certain character] there is found to occur another group of teeth resembling those in the preceding series (tritt wieder ein übereinstimmender oder doch ähnlicher auf). At first sight one gets the impression of complete lack of order in the arrangement; but closer study shows that the successive series are not devoid of regularity."

A similar arrangement of the lateral cusps in *Benthoctopus berryi* has been recently described (Robson, 1924); and the following pages give a detailed account of the phenomenon and its distribution in the Octopodidae, together with as much information as is available on the subject of its origin.

Nacé, in the passage quoted above, indicated that both asymmetry of cusp-arrangement and serial repetition are found in *Octopus vulgaris*; and the same two phenomena were recorded by myself for *Benthoctopus berryi*. Needless to say, the occurrence together of two such phenomena is a very remarkable fact, for the arrangement of radular teeth in metamerically repeated series and any regularly recurring asymmetry are unknown in other molluscan radulæ.

To present a clear picture of what occurs in the radula of *O. vulgaris*, which we may describe as illustrating these two phenomena, it is necessary at first to give a brief account of the radula and its mode of formation. It consists of numerous transverse rows each containing nine teeth. In the

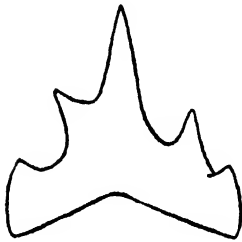


FIG 1  
OCTOPUS VULGARIS  
Radula median tooth Camera .93

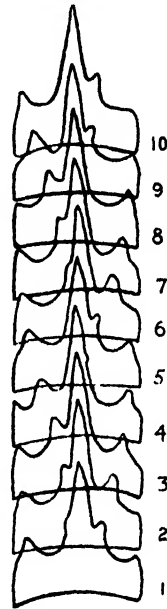


FIG 2  
OCTOPUS VULGARIS  
Median teeth of successive rows  
partly diagrammatic

median tooth of every row there is a large median cusp or mesocone with two lateral cusps (ectocones) on each side of the main one (fig. 1). The radula is formed, as usual, in the radular cæcum, and is pushed forwards into the cavity of the mouth, new teeth being added at the base or formative area of the cæcum as the more anterior (and older teeth) are worn down. So far, the median tooth of *Octopus vulgaris* does not differ in essentials from that of most other molluscan genera. But if we follow the successive median teeth from the oldest to the youngest, it becomes obvious that the number and position of the ectocones are variable. In fig. 2 the tooth numbered 1 is

formed earlier, and is therefore older than No. 10, which is the most recently formed. If the series 1-10 is followed attentively, it will be seen that the ectocones of either side are arranged in metamERICALLY repeated groups of five. If one of these groups is studied, it will be seen that the ectocones change their position regularly. Within each series of five teeth, if we follow the series from the older teeth to the younger, an inner ectocone appears high up on the side of the mesocone, and, in the subsequently developed teeth, shifts its position downwards and outwards, and finally becomes the outer ectocone. This change of position occupies five teeth, after which a second ectocone makes its appearance on the main cusp and starts to move outwards in the same fashion.



FIG 3  
OCTOPUS VULGARIS  
Diagram of cusps of successive  
main teeth

Moreover, it will be seen by a comparison of the two sides that this seriation is not symmetrical. The five teeth of a series which on the right side show a complete transition-period of the inner ectocone do not show a complete period on their left side. On the left side the transition period of the inner ectocone occupies five different teeth, the series on the left and right being regularly alternating. The series of one side is three teeth behind, or two in front of \*, that on the other. The representation given in fig. 3 shows the disposition of the cusps diagrammatically.

\* Owing to the imperfect condition of the teeth, it is impossible to be certain, even if stained preparations are used, which is the first-formed series.

From this it will be seen that, in the species in question, the median tooth is subject to a serial repetition in which the inner ectocones change their position centrifugally in successive teeth, resuming their normal point of appearance on every fifth tooth ; and that this seriation is not symmetrical, but regularly alternating.

The significance of this phenomenon in terms of growth and its possible origin are discussed in Part 3. It remains at this point to add that the condition described above is found over as much of the radula as is available for close examination. Among the most immature teeth and at the worn extremity it is, of course, impossible to make certain of what occurs. It should likewise be stated that a certain amount of irregularity is found. The teeth in a series vary from four to five, while the fate of the ectocones is sometimes uncertain.

## 2. DISTRIBUTION OF SERIATION AND ASYMMETRY IN THE RADULA OF THE OCTOPODIDÆ ETC.

As we have already seen, two separate phenomena are involved in *O. vulgaris*, viz. seriation and alternation in cusp-formation. From the data presented below it will be seen that the two phenomena are not inseparable, and seriation alone is the more common among the forms investigated.

Asymmetry or cusp-alternation seems to have been noticed by Troschel (1853) in *Moschites moschata*, though he made no comment upon it. It is conceivable also that Lovén may have observed it (1847). Serial repetition of similar teeth was recorded without comment by Steenstrup in *Eledonella diaphana* (1858), while several figures of *Octopus radulæ* (e.g. that given by Massy, 1916, p. 149) show a change in the position of the ectocones, though no remark is made on the subject.

A careful survey of all the material available in the Zoological Department, British Museum, and of material kindly lent by Lt.-Col. A. J. Peile has shown me that the radulæ of *Octopus*, *Moschites*, *Scœurgus*, and probably *Eledonella* show one or both of these phenomena in a very high percentage of cases. Serial repetition is more frequent than the combination of seriation and alternation. In all, I succeeded in obtaining twenty-two specimens of *Octopus*, five of *Eledone*, and one each of *Scœurgus* and *Eledonella*. A tabular statement of the condition found in each is given below. The data are arranged in two main groups according to the symmetry of the seriation. Within each group the cases are grouped according to the number of teeth constituting a series. This arrangement is adopted for the sake of convenience. It is not known at present whether there is any significance in the grouping.

A graphic representation of the change in position of the ectocones may be given by means of the following simple formula. The two ectocones of each side (inner and outer) are designated *a* and *b* respectively, and the large

mesocone is represented by the symbol I. The change of position of the inner ectocones on each side of the main cusp is indicated in a typical case of simple seriation thus:—

$$\begin{array}{l} b - a \text{ I } a - b \quad \dots\dots\dots (I) \\ (ba) - \text{I} - (ab) \quad \dots\dots\dots (II) \end{array}$$

The first line (I) of the formula represents an older tooth than (II). In the older tooth *a* (the inner ectocone) is adjacent to the main cusp; in (II) it has migrated outwards and is fused with the outer ectocone *b*. If there are three teeth in a series the formula in a typical case would be:—

$$\begin{array}{l} b - a \text{ I } a - b \\ b - a - \text{I} - a - b \\ (ba) - \text{I} - (ab) \end{array}$$

Asymmetrical seriation is shown as follows (in a typical case with four teeth to a series):—

$$\begin{array}{l} a' - a \text{ I} - a' \\ a' - a - \text{I} - a - a' \\ - a - \text{I} - a - a' \\ a' - \text{I} - a \\ a' - a \text{ I} - a' \\ \text{I} - a - a' \end{array}$$

In such a case as this, where there is no persistent outer ectocone, each originally inner ectocone eventually assumes a marginal position, and the inner ectocones of a series are actually the outer ectocones (*a'*) of a subsequent series.

It should be pointed out that this cusp-formula is arbitrary. The indication of a cusp by means of a symbol *a* or *b* does not imply that in all cases the identity of a cusp *a* is the same. It is necessary to make this clear, because of the difficulty of identifying the outer ectocone. In certain cases, *e. g.*, in *Octopus tehuelchus*, the latter is certainly not persistent, and in the formula given on p. 105 *a'* is certainly part of the same formative impulse as gave rise to *a*. In other words, *a'* is evolved from *a*. But in other cases when there is a persistent outer ectocone, it is very uncertain whether the inner ectocone fuses with it or disappears. In the first case we would write our formula:

$$\begin{array}{l} b - a \text{ I } a - b \\ (ba) - \text{I} - (ab); \end{array}$$

in the second:

$$\begin{array}{l} b - a \text{ I } a - b \\ b - \text{I} - b. \end{array}$$

In practice it is very difficult to decide this.

We should likewise make it clear that in cases of a simple seriation consisting of two rows we have no means of deciding whether we should regard

the movement of the inner ectocone as centrifugal or centripetal, *i. e.* whether we should write our formula :—

$$\begin{array}{ccc} b - a I a - b & & (ba) - I - (ab) \\ & \text{or} & \\ (ba) - I - (ab) & & b - a I a - b \end{array}$$

As in the more complex cases with four or five teeth in a series the older teeth always have the inner ectocone internal to begin with, it seems a safe inference that the tendency is *always* centrifugal.

### Octopus.

#### A. Symmetrical seriation.

##### 1. Two teeth in a series.

OCTOPUS ARBORESCENS, Hoyle.

(One example : Cargados I.,  
Indian Ocean.)

$$\begin{array}{ccc} a I a & & \\ a - I - a & & \end{array}$$

O. FONTANIANUS, D'Orb.

(Two examples : Coetivy I.,  
Indian Ocean and ?.)

$$\begin{array}{ccc} b - a I a - b & & \\ (ba) - I - (ab) & & \end{array}$$

This is a very peculiar case. The teeth definitely alternate in pairs ; but in the only specimen available for satisfactory examination there is a change of rhythm at the 18th and 36th row. Within the first eighteen rows there is a gradual change of such a nature that while the double-cusped teeth are in the even rows and the single-cusped ones in the odd rows (counting from the youngest tooth of all) in the younger teeth, in the older ones the reverse is the case, the complete change becoming manifest at about the eighteenth tooth. On the thirty-sixth tooth there is a change back to the original alternation. In short, we seem to have a double rhythm : viz. an ordinary seriation in pairs and a more sustained and slower change in the character of the pairs which is extended over eighteen teeth.

O. RUGOSUS (Bosc). (Indo-Atlantic form.)

(Two examples : Cape Town.) Formula as in *O. fontianus*.

The same double alternation of rhythm is seen as in *O. fontianus*. In the better-preserved example the 10-14 more recently-formed teeth are uniform.

O. OCCIDENTALIS, Hoyle.

(One example : S. Trinidad.)

Resembles *O. fontianus* in that there is an additional seriation.

O. sp.

(One example : Cape Verde I. Gwatkin coll. 31715.)

This form agrees with the preceding, but the specimen is not in a very good condition, and, in any case, the sequence of the ectocones is somewhat irregular.



## 2. Three teeth in a series.

**OCTOPUS GARDINERI, Robson.**

(One example : Coetivy,  
Indian Ocean.)

$$\begin{array}{ccccccc} & - & - & - & - & a & \textbf{I} & a & - & - & - & - \\ & & & & & - & a & - & - & - & - & \textbf{I} & - & - & - & a & - & - & - \\ a & - & - & - & - & - & - & - & - & - & \textbf{I} & - & - & - & - & - & - & - & - & a \end{array}$$

**O. HORRIDUS, D'Orb.**

(Two examples: Amirante I.) Formula as in *O. gardineri*.  
A little less regular than *O. gardineri*.

**O. DEFILIPPI, Vérany.**

(One example : Nice.)

Possibly like *O. horridus*, but rhythm obscure.

3. Four teeth in a series.

O. SALUTII, Vérany.

(One example: Naples.)

$$\begin{array}{ccccccc} -a' & - & - & - & - & a & 1 \\ a' & - & - & - & - & a & 1 \\ a & - & - & - & - & a & 1 \\ - & a & - & - & - & a & 1 \\ - & a & - & - & - & a & 1 \end{array}$$

**O. GRANULATUS, Lamarck.**

(One example : Madras.)

Formula as in *O. salutii*, but a permanent ectocone is possibly found.

**O. verrucosus, Hoyle.**

(One example : Funafuti I.)

Formula as in *O. salutii*, but rather irregular.

Uncertain formula:—(C). HORSTL.

### B. Asymmetrical seriation.

1. Four teeth in a row.

**OCTOPUS TEHUELCHUS, D'Olb.**

(One example : Falkland Is.)

$$\begin{array}{cccccccc}
 a' & - & - & - & - & a & 1 & - & - & - & - & a & - \\
 a' & - & - & - & a & - & 1 & a & - & - & - & a' \\
 a' & - & - & a & - & - & 1 & - & a & - & - & a' \\
 - & a & - & - & - & 1 & - & - & a & - & - & a' \\
 a' & - & - & - & - & a & 1 & - & - & - & a & a' \\
 a' & - & - & - & a & - & 1 & a & - & - & - & a' \\
 a' & - & - & a & - & - & 1 & - & a & - & - & a' \\
 - & a & - & - & - & 1 & - & - & a & - & - & a'
 \end{array}$$

Though the asymmetry is marked and recurs regularly, there is a certain amount of variation in the occurrence of the outer ectocone. I do not think, however, that it is persistent.

**O. RUGOSUS (Bosc). (Atlanto-African form.)**

(One example: Rio de Janeiro.)

As in *O. tehuelchus*, the permanence of the ectocone is variable. Formula as above.

*O. sp.?* (? a variety of *vulgaris*). Formula as above, but irregular.

O. (BENTHOCTOPUS) BERRYI,  
Robson.  
(One example: Natal.)

- a - - - - - a I - - - - - a - - - - - a'  
- a - - - - - a - l - - - - - - - - - - a'  
a' - - - - - a - - l a - - - - - a -  
a' - - - - - a - - - I - - - a - - - - - a -  
- - a - - - - a I - - - - - a - - - - - a'  
a' - - - - - a - l - - - - - a - - - - - a'  
a' - - - - - a - - I a - - - - - a - -

2. Four to five teeth in a series.

O. VULGARIS, Lam.  
(Three examples: Plymouth;  
Brighton; Vigo.)

a' - - - - - a l  
a' - - - - - a - - I  
- - a - - - - I a - - - - - a'  
- - a - - - - l - a - - - - - a'  
a' - - - - - l - - - a - - - a'  
a' - - - - - a l - - - - - a -  
l - - - - - a'  
l a - - - - - a'

O. sp. (? VULGARIS, var.)

(Two examples (A. J. P.):  
English Channel.)

Formula as in *O. vulgaris*.

Seriation present, but arrangement of cusps uncertain.

O. PUNCTATUS, Gabb.

(Two examples: W. Atlantic.)

### Moschites.

A. *Symmetrical seriation.*

Two (occasionally three) teeth in a series.

M. MOSCHATA (Lam.).

(One specimen: Naples.)

a' - - - - - a l a - - - - - a'  
- a - - - - - - I - - - - - a -  
a' - - - - - a l a - - - - - a'  
etc.

M. BREVIS (Hoyle).

(One specimen: Rio de Janeiro.) Probably as in *M. moschata*.

B. *Asymmetrical seriation.*

None of the remaining examples (*M. aldrovandi*, Chiaje; *M. charcoti* (Joubin); and *M. turqueti* (Joubin)) were in very satisfactory condition, but they showed distinct traces of recurrent asymmetry.

### Scaurgus.

The only specimen of this genus available (an example of *S. tetracirrhus*, Chiaje, from Naples) shows symmetrical seriation; but a curious and interesting "lag" occurs. The new ectocone of each series appears on the same tooth, but one side is invariably rather less developed than the other.

### **Eledonella.**

Steenstrup (1858) has recorded a seriation for *E. (Bolitaena) microcotyla*. In *E. massysæ*, Robson, I find that there is a symmetrical seriation similar to that of *Octopus*, a fresh ectocone appearing on every fifth rhachidian tooth, which is an agreement with Steenstrup's description.

### **Amphitretidæ.**

Naef, in the passage quoted above (p. 99), compares the modification of the ectocones in *O. vulgaris* to a similar condition in the Amphitretidæ. I am unable to verify his statement, but Thiele (1915), who described the radula of *A. pacificus*, does not allude to any seriation or asymmetry.

### **3. DISCUSSION.**

The asymmetrical mode of growth described above is unique among the Mollusca, both for the radula and for any other organ. The alternating centrifugal cusp-series seems to represent a branching growth-system similar to that found (*e. g.*) in Anthozoa and other Cœlentera, though such an analogy cannot be pressed. Unfortunately, nothing is known of the Cephalopod radula that casts any light on the origin of a phenomenon which appears to be well established among the Octopodidæ. With regard to the symmetrical seriation, we are in a little better position.

The development of the radula has had a very full measure of attention paid to it in the past, notably by Roessler (1884), Bloch (1896), Sollas (1907), and Spek (1919). According to these authors, the teeth originate from a special area of large cells (odontoblasts) situated at the base of the radular cæcum on the ventral side. Each tooth is formed by a group of odontoblasts. In the Cephalopoda and Prosobranchia, Roessler found that the cells in the groups of odontoblasts are smaller and more numerous than in the Opisthobranchia and Pulmonata. Bloch was of the opinion (*l. c.* p. 382 *et seq.*) that the odontoblasts are periodically replaced by others. With regard to the special problem of cusp-development in the Cephalopoda, I can find nothing in the work on the subject by Kölliker (1857), Roessler (*l. c.*), and Rothman (1901) that throws any light on the way in which the centrifugal migration of the ectocones described above may be brought about. In general, however, the actual seriation may be due to the periodical replacement of the odontoblasts suggested by Bloch. If this is so, the outward migration of the ectocones may be the result of an outward movement of the secretory masses elaborated by each new set of odontoblasts. In each formative period expressed in the development of the successive teeth of a series the secretory activity may spread over a gradually widening field, and thus in successive teeth the centre of this activity may pass outwards. In this connection it should be noted that the first ectocone of

a series (that which occupies the inmost position) is invariably small and weaker than the succeeding and more external ones.

Against this suggestion and the theory of periodical activity on the part of the odontoblasts, may be set the fact that no positive cases of similar condition are found in Prosobranch radulæ in which a multicuspid rhachidian tooth is found.

With regard to the asymmetrical seriation, we have, as has been said, no evidence on which to build even a tentative explanation. There is a remote possibility that we are dealing with an adaptational phenomenon. The asymmetrical arrangement of the cusps may afford a better means of rasping a certain kind of food, in that in any given median tooth there is always a strongly-developed ectocone available, while in the symmetrical type with several teeth to a series there are always points at which two weakly-developed ectocones (the first of a series) coincide.

One is tempted to see in the occurrence of serial repetition here involved a trace of primitive metameric segmentation. I do not think, however, that the evidence at present available is sufficient to justify a serious discussion of this possibility.

#### 4. SUMMARY.

(1) The radulæ of certain Octopodidæ have multicuspid median teeth. In many species these teeth exhibit a serial arrangement in which the ectocones in successive sets of teeth occupy a progressively more external position.

(2) In certain species this seriation is alternating, the series on the opposite sides of the main cusp not being coincident.

(3) The distribution of this phenomenon, unique in the Mollusca, is described among the genera of the family; and some attempt is made to find an explanation for the serial arrangement in the developmental history of the radula.

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A Revision of the Family Anthuridæ (Crustacea Isopoda), with Remarks on certain Morphological Peculiarities. By K. H. BARNARD, M.A., F.L.S., F.R.S.S.Afr.

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(With PLATE 4 and 10 Text-figures.)

[Read 5th March, 1925.]

THE following paper began (in 1917) as a morphological-biological study of the various forms of the tail-fan in the South African Anthurids. This study disclosed certain rather interesting facts, which, it seemed, might gain in value by being confirmed in species from other parts of the world.

For this purpose I have fortunately been able to examine a considerable amount of material from several sources as acknowledged below, with the result not only that my previous observations were fully confirmed, but that several other morphological features, to which adequate attention had not been given by previous authors, were studied. I was thus led to make a revision of the whole family from the systematic point of view. Yet I would not have this Revision regarded as more than a preliminary study of the family.

As was to be expected, some changes in nomenclature were inevitable. As in all families to which isolated species have been added by various authors, the component genera were ill-defined and, as it happens, established in complete ignorance of some of the fundamental characters. In the old days species were dumped into "*Anthura*" or "*Paranthura*," and consequently both genera became jumbles of widely differing forms. Even in 1914 an author complains that he is not clear as to the difference between *Paranthura* and *Leptanthura*, although here there is no excuse in view of the accurate figures of a species of the latter genus given by Sars.

The large amount of material that has passed through my hands has enabled me to define the genera more clearly, and the diagnoses of them will, I hope, do away with some of the major difficulties that have hitherto beset the student of this family. Some questions of specific synonymy still remain to be cleared up by workers having access to the types.

Twenty-one new species and seven new genera are here proposed. The types of all the new species are in the respective Institutions from which the material was obtained.

The sources of my material, in addition to that belonging to the South African Museum, were as follows :—

Dr. Chilton sent me a most useful collection of Australasian species. The Adelaide Museum forwarded the whole of its Isopod collection, from which I was able to pick out many S. Australian and Tasmanian examples of this family. Through Dr. Calman's kindness I was able, when in London in 1920, to study the whole Anthurid material in the British Museum. This was especially useful as it contained several cotypes of Haswell's Australian species which were badly in need of re-examination and the types of which the Australian Museum in Sydney was unable to send me owing to the regulations not permitting types to leave the Museum.

Some material of the 'Travailleur' and 'Talisman' collections in the Paris Museum was examined, and the United States National Museum sent two species. This Institution also was unable to send types, and other types in the Peabody Museum at Yale were packed away in storage and could not be got at.

By far the finest and most important collection examined was that belonging to the University Museum at Copenhagen, which Dr. K. Stephensen kindly sent to me in London. This collection, from which most of the new species were derived, was not only richer in species and individual specimens than any other, but contained specimens from regions whence I had no other material.

To all these gentlemen and Institutions I wish to tender my best thanks for so kindly placing their material at my disposal.

### I. MORPHOLOGY.

No attempt at a complete account of all the morphological features is here intended. Only some of the features, concerning chiefly the exoskeleton, which are of importance from the systematic point of view are dealt with. Further interesting studies, for example, might be made of the varying development and degeneration of the eye, from the bulging morula-like eyes of the free-swimming *Anthura gracilis* down to the mere white specks of the "blind" species; and of the medio-dorsal pits found on the 4th–6th pereon segments in certain genera.

Concerning the internal anatomy we have scarcely any information except Dohrn's account of a species of the genus *Paranthura* (1869).

*Size*.—Anthurids do not reach a very large size, the largest known being : *C. brachiata* 45.5 mm., *A. gigas* 42 mm., and *C. carinata* 27 mm. in length. The smallest species are *C. indica* 3.5 mm., and *Xenanthura brevitelson* 4 mm. A point to be noted, however, is that adults of the same species often vary considerably in size. Thus, I have measured ovigerous females of *C. brachiata* from 3.5 mm. to 8 mm. *L. glacialis* is recorded by Hodgson as 21 mm. long, and by Tattersall as 10 mm.

It is important to bear in mind this variability in the size of the adult in discussing certain questions of synonymy (see e. g. *A. sladeni*, infra p. 149).

*Antennæ*.—The upper or first antennæ are remarkable for the secondary sexual modification displayed in the males of certain species in both Sections A and B.

Apparently two ecdyses are necessary to bring about this modification, but this point has never been definitely determined. At the last moult, however, the flagellum appears like a bottle-brush, with dense whorls of setæ, varying in length in the different species, but usually long, springing from each joint. The joints are much swollen and broader than long and their limits are obscured. The peduncle likewise becomes swollen though the joints remain distinct.

This sexual feature appears to be a comparatively recent acquisition, speaking phylogenetically. In its fully developed form it appears in *Anthura*, *Leptanthura*, and other genera. It is thus not correlated with a degeneration of the eye, as it appears equally in the prominent-eyed *A. gracilis* and in the "blind" species of *Leptanthura*. Perhaps with increase in our knowledge of the family the enlarged brush-like flagellum will be found in the males of the majority of the species.

Where the antenna is not modified the flagellum resembles that of the female and is short and pauciarticulate, or even composed of a single joint.

There is one case, namely *Pseudanthura lateralis*, which may be regarded as a transition in that only the four basal joints are swollen, the others being slender and elongate, and only the first six joints bear whorls of setæ.

The lower or second antennæ exhibit no marked sexual dimorphism. The flagellum is usually pauciarticulate or even reduced to a single joint, and is nearly similar in both sexes. In *Paranthura* the flagellum consists of a most characteristic single flattened joint.

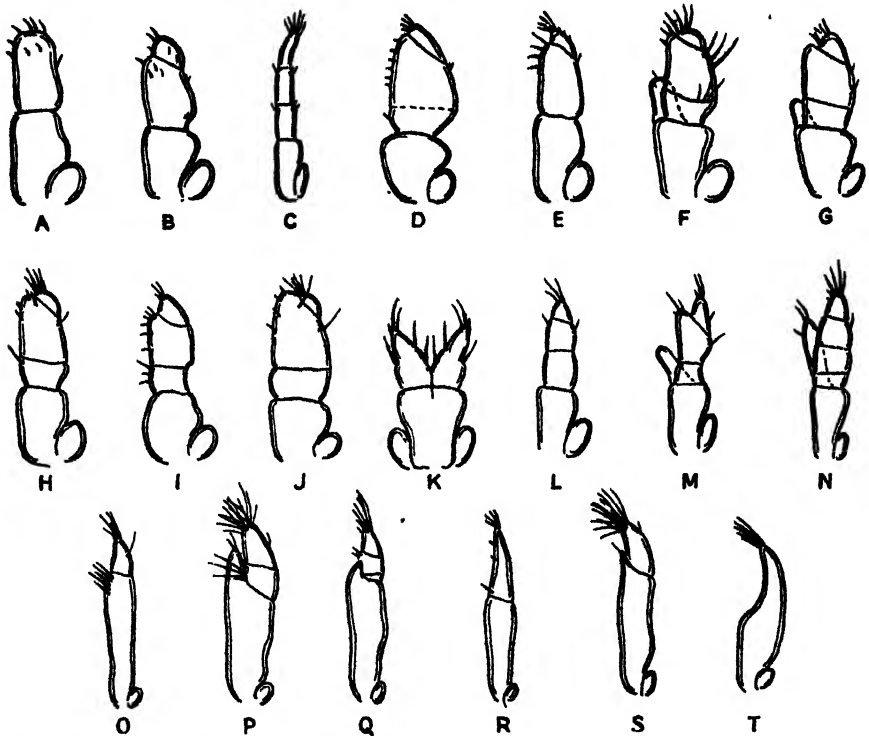
One of the most curious morphological features in the whole family is the presence on the 2nd antenna in *Xenanthura* of a second flagellum or exopod (text-fig. 8, p. 139). This is especially interesting in view of the fact that the exopod is absent throughout the whole of the Isopoda except in some Asellota. It is present also in the Apseudidæ among the Tanaidacea. In these exceptions the "scale" which is considered to represent the exopod is at the end of the 2nd peduncular joint in the Apseudidæ and the 3rd joint in the Asellota. The "peduncle" therefore in these groups is not synonymous with "protopodite," but is merely a convenient descriptive term for the few large heteromorphous joints as opposed to the more or less numerous small homomorphous joints composing the flagellum. In *Xenanthura* the small two-jointed appendage regarded as the exopod is attached to what appears to be the *fourth* joint of the peduncle.

The *Mandibles* call for little comment, for though there are differences in the palps and in the teeth of the cutting-plate in Section A, I have not found

it always practicable to use these differences as generic characters. Sometimes a genus is well characterised by a constant form of palp (e. g. *Leptanthura*), whereas in other genera it may happen that one species will spoil the harmony. To lay too much stress on the mandibular palp would be to run counter to a generic arrangement based on more important characters.

Reduction of the palp occurs in *Ptilanthura*, where it is reduced to a single joint, and in *Xenanthura*, where it is represented by a seta only (text-fig. 8). In *Cruregens* there is no trace of the palp.

FIG. 1.



Maxillipeds of:—A. *Anthura*; B. *Exanthura*; C. *Eisothistos*, ♂; D. *Haliophasma*; E. *Cyathura*; F. *Antheura*; G. *Ananthura*; H. *Apanthura*; I. *Mesanthura*; J. *Skuphonura*; K. *Xenanthura*; L. *Kupellonura*; M. *Hysura*; N. *Panathura*; O. *Leptanthura*; P. *Accalathura*; Q. *Calathura*; R. *Paranthura*; S. *Pseudanthura*; T. *Cruregens*.

All figures from actual specimens, but not all to same scale. The first joint, which is fused to the head, is not shown.

*Maxillipeds*.—These appendages are of far more importance than the mandibles, and nearly every genus is characterised by a well defined and constant form. This is especially true of Section B. In Section A we have a genus (*Haliophasma*) where the number of joints may be 4 or 5 in the several species according to the absence or presence of one suture, but



the general shape remains the same and in other respects these species are obviously congeneric.

The largest number of joints in the maxilliped is 6. The 7th joint, which may be presumed to have been present originally, has only been met with in *Panathura serricauda* as a minute and obscure rudiment. We find all stages in the reduction of the number of joints to two. It should be noted that throughout this paper the basal joint, which is ankylosed to the head, is counted in the number of joints though it is not shown in the figures and is rarely seen in microscopical preparations.

The figures here given (text-fig. 1) of the various forms of this appendage need no description. *Xenanthura* is remarkable for having the 2nd joints completely fused with one another.

Reference may be made to the supposed abnormal maxilliped of *Anthura gracilis* figured by Sexton (1914). From the shape of the joints and the fact that throughout the family the 2nd joint is always longer than the epipod, it seems clear that the joint in which the supposed extra suture is figured is the 2nd joint and therefore one in which an extra or an obsolescent suture is most unlikely to occur. It is in the portion *distal* to the 2nd joint, often referred to as the palp, that variations in the number of joints or sutures occur. I regard the supposed extra suture merely as a crease or crack in the 2nd joint produced either during the animal's life or in the course of mounting for examination.

*Peræopods*.—The peræopods are rather important from the systematic point of view. Peræopod 1 has nearly always the 6th joint (propodus) subchelate, but in *Eisothistos* this joint is quite simple and in *Ananthura* it approximates to the simple cylindrical form. The unguis of the 7th joint is always short in Section B, but may be shorter than or as long as the joint in Section A.

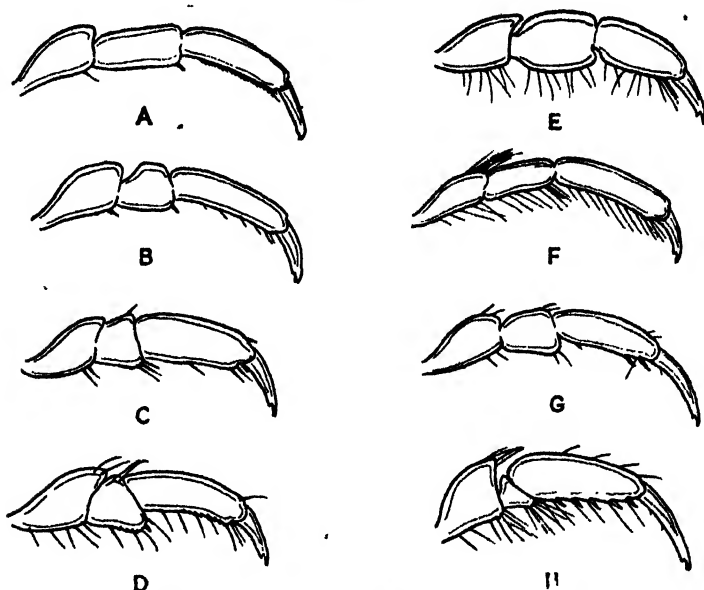
Occasionally there is sexual dimorphism. In *Anthura gracilis* the female has the 1st leg stout and strongly subchelate, almost chelate, while the male has it much more slender and with a simple 6th joint. In *Pseudanthura* the dimorphism is not so strongly marked, but here also it is the female that has the stouter leg.

The 2nd and 3rd peræopods in general resemble the 1st peræopod. The 5th joint is always triangular and underriding the 6th. The 6th joint is cylindrical or slightly ovate in Section A, but distinctly ovate in Section B, *i. e.*, in the latter group these peræopods are prehensile and consequently serve as a ready means of separating the members of the two Sections in a mixed collection. *Hyssura* and *Xenanthura*, however, are exceptions since they have the 2nd and 3rd peræopods almost or quite as large as the 1st. In *Anthura gracilis* these peræopods appear to be somewhat stouter in the female than in the male.

The posterior four pairs of peræopods are similar to one another, and the only point that requires attention is the shape of the 5th joint. This

varies between two extremes: it may be cylindrical and about as long as the 6th joint, or very short, triangular or underriding the 6th joint. Transition forms are found with the 5th joint cylindrical but much shorter than the 6th, or subtriangular with a very short upper margin (text-fig. 2). Both types of 5th joint and transitions occur in both Sections, and the 5th joint underrides the 6th to an extreme extent in *Leptanthura*. The shape of the 5th joint is therefore an important generic character. In practice there is no difficulty in deciding whether the 5th underrides the 6th or not.

FIG. 2.



Fourth to seventh joints of the 6th pereopod of:—A. *Anthura*; B. *Ananthura*; C. *Kupelionura*; D. *Apanthura coppingeri*; E. *Hyssura profunda*; F. *Accalathura*; G. *Calathura*; H. *Leptanthura*.

All figures from actual specimens.

*Oostegites*.—The formation of the oostegites proceeds in a manner different from that found in most Isopods, according to the observations of Dohrn (1869). He states that the ventral skin splits into two layers, an inner which forms the ventral body-wall and an outer which forms the brood lamellæ. These observations have never, I believe, been confirmed, but it is certain, at all events, that the oostegites appear, fully formed, at a single moult. When one examines large numbers of Isopods of other families (with certain exceptions) in various stages of growth, the young females can generally be separated by the incipient brood lamellæ which arise as outgrowths near the bases of the pereopods and increase in size with each moult. But I have never seen an Anthurid with incipient brood lamellæ at the bases of the pereopods, and where a particular specimen is not

ovigerous and lacks the male primary and secondary sexual characters, it seems impossible to determine its sex from the external features.

The usual number of lamellæ is four pairs, on segments 2-5. Some species, however, have only three pairs, the first pair belonging to segment 2 being completely absent.

This reduction in the number of lamellæ occurs quite sporadically in several genera in both Sections A and B, but not in more than one species in each genus (except *Cyathura*), so far as yet known. There appears, therefore, to be a tendency in the family towards a concentration of the brood-pouch; and as it is the anterior lamellæ which disappear, this concentration is towards the middle of the animal's body. Compare the similar phenomenon in the genus *Tanais* and other Tanaisids. It may be observed that the structure and growth of the lamellæ in *Tanais* might repay investigation, although I am unaware whether Dohrn has dealt with this point in any of his papers.

All the lamellæ are similar in structure, being thin and transparent with two feeble supporting rods arising near together at the base and diverging. The first pair are somewhat smaller than the following pairs.

Boone stated (1920, p. 31) that in *Paranthura* (*Calamura*) *porteri* there were six pairs of plates composing the marsupial pouch. As the presence of six pairs of oostegites seemed, in view of my experience of other Anthurids, so extraordinary, I requested the loan of the type from the United States National Museum. This was courteously granted, and examination showed that Boone was mistaken. There are only the normal four pairs of oostegites in this species. Dr. Waldo L. Schmitt also found only the four pairs on the specimen.

*Pleopods*.—The 1st pleopod is operculiform and covers the other pleopods except in *Hyssura*, *Xenanthura*, and *Kupellonura*. Only the outer ramus however is enlarged, the inner remaining small and narrow. The outer ramus is sometimes strongly indurated and often sculptured with pits or impressed lines which may be used as specific characters.

In all the pleopods the outer ramus is anterior to the inner ramus, and in pleopods 2-5 the two rami are subequal in size. *Eisothistos* forms an interesting exception in that the two rami lie side by side (text-fig. 3). This genus is also exceptional in having the two rami in the 1st pleopod completely fused along their entire length, leaving only a minute notch on the distal margin to indicate the fusion (see Haswell's fig. 1, pl. 37, 1884); the whole is operculiform. In the other pleopods the rami are distinct, but the outer is considerably smaller than the inner.

As regards the character of the male stylet on the 2nd pleopod there are few records\*. As a matter of fact males with the stylet developed are,

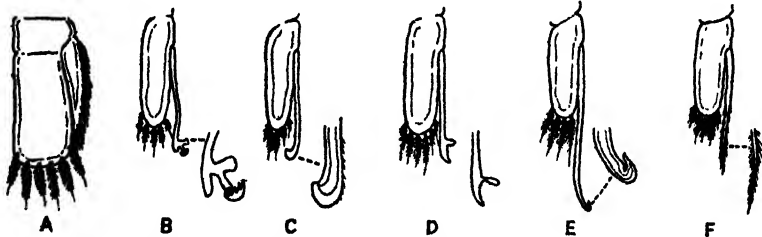
\* Omer Cooper refers to the peculiarity of this appendage in *Cyathura carinata*, and states that no description appears to have been published (Zoologist, vol. xx, 1916, p. 26).

I find, very much rarer than in other families of Isopods. In most cases the stylet is a narrow elongate rod with a simple subacute or rounded apex. Sometimes the apex is slightly or distinctly hooked, or even complex, as will be seen from the figures here given (text-fig. 3).

*Branchial Chamber.*—The operculiform 1st pleopods form the bottom of a branchial chamber containing the remaining four pairs of pleopods which act as gills. The distal margin of the 1st pleopods is more or less densely fringed with plumose setæ and in most cases they reach almost to the end of the telson. (Sexton's statement as to their length in the femule *Anthura gracilis* is scarcely correct.)

The lateral walls of the branchial chamber are formed by the peduncles of the uropods which are always thicker on the outside margin, a transverse section being wedge-shaped. As a rule, they close below the telson, *i. e.*, between the telson and the 1st pleopods, but to close the chamber more securely along the sides a distinct and often strong keel is developed on the

FIG. 3.



- A. 2nd pleopod of *Eiothistos vermiformis* (otype Brit. Mus.). 2nd pleopod, endopod with  $\delta$  stylet, of:—B. *Cyathura carinata* (Christchurch, England); C. *Cyathura crucis* (W. Indies); D. *Accalathura crenulata* (W. Indies, Paris Mus.); E. *Pseudanthura lateralis* (S. Africa); F. *Calathura brachiata* (N. Atlantic), with a single seta enlarged.

under side of the peduncle. The keel is fringed on its edge and apex with plumose setæ. It is particularly strong in *E. macrura* and also in *A. gracilis*.

A very complete branchial chamber is thus formed, and it varies but little in general form. It is not quite so perfect in those forms, *e. g.* *Mesanthura*, in which the keel is not so prominently developed. The branchial chamber of *Pseudanthura*, however, deserves special mention. In this genus the telson has been shortened so that its apex lies level with the apices of the 1st pleopods, which are not broadly rounded as is usual in the family, but taper to a point in conformity with the telsonic apex. An exactly similar closing of the branchial chamber is effected in the *Astacillidæ* by the telson and uropods.

The lateral gap is closed as usual by the peduncle of the uropod, which is of the usual triquetral shape. This appendage, as far as its apex, which just coincides with that of the telson, seems capable of such close and accurate

juxtaposition with the lateral edges of the telson above and of the 1st pleopods below that no setæ, simple or plumose, are required to exclude particles of extraneous matter. There are only a very few simple setæ on the outer distal margins of the 1st pleopods.

This form of branchial chamber seems to be an adaptation to a muddy habitat, for the genus apparently lives only at considerable depths on a fine muddy bottom. Compare the similar tightly closing branchial chamber in *Haploniscus*, *Macrostylis*, *Heteromesus*, and other Asellota also found on muddy bottoms.

In *Hyssura*, *Xenanthura*, and *Kupellonura*, since the 1st pleopods are not operculiform, no branchial chamber is present. These forms may be regarded as primitive and unspecialised so far as this feature is concerned.

*Tail-fan*.—This is the most characteristic feature of the family and is extremely important for both generic and specific differentiation. Yet it seems to have received but scant and superficial attention in the past. Most authors have considered the telson as if it were a plane figure with no dimensions but length and breadth. In no species has the telson been adequately described, not even in *Anthura gracilis*. As regards the uropods, these appendages have as often as not been figured in the foreshortened position in which they appear *in situ* in a dorsal view of the animal, so that it is impossible to judge of their true shapes.

From the following observations it will be seen that the transverse section of the telson is as important as its superficial outline. It should always be examined either while still attached to, or better detached from, the animal in a semi-dry (not desiccated) condition, not submerged in liquid.

As regards the homology of the parts of the uropod, I have followed the usually accepted view that this appendage consists of an elongate peduncle bearing at its apex a one-jointed endopod (inner ramus) and near its base dorso-laterally a one-jointed exopod (outer ramus). Chilton's arguments derived from *Cyrcogens* and *Hyssura* seem conclusive, but might be strengthened by an appeal to *Pseudanthura*, the uropod of which is exactly comparable with that of one of the Sphæromid genera with reduced exopod (e. g. *Cassidina*).

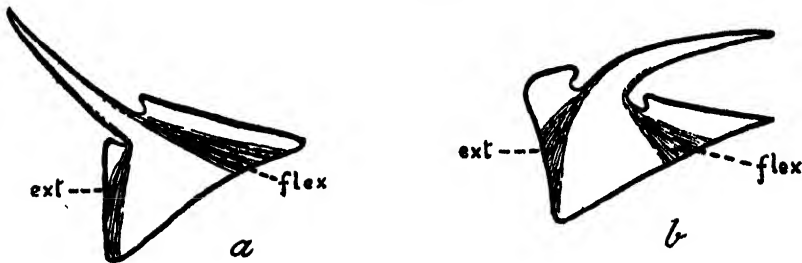
In transverse section the telson varies much in shape. It may be lenticular, circular, plano-convex or concavo-convex (the convexity being either dorsal or ventral), or trapezoidal, the outline being modified in some cases by the presence of grooves, pits or ridges. Examples of each type are figured (see Plate 4), and descriptions are given in the systematic part, so that further remarks are here superfluous. We shall deal later with that remarkable feature of the Anthurid telson—the statocyst.

The next point is the shape of the "tail-fan"—i. e. the telson and uropods—as a whole. Although it has been recognised that the tail-fan may be either open and shallow like a saucer or half-closed and deep like a cup

or flower-bud, the biological significance or the morphology of the two forms seems never to have been investigated.

The shape of the tail-fan depends primarily on the position of insertion of the exopod of the uropod and the extent to which it can be moved outwards or inwards. Take the case of *Anthura gracilis*. Bate and Westwood (1868) say that the outer plate "when at rest . . . falls back and shuts down upon the dorsum" of the telson. In the figures of Norman and Stebbing (1886) and Sexton (1914) this plate is represented as standing up nearly at right angles to the telson. From examination of actual specimens I am unable to confirm Bate and Westwood's statement. The exopod will *not* bend *inwards* further than the position indicated in the figures of the later authors. But from here it is freely movable *outwards* to a position which is the continuation of the curve of the telson and endopods. The total extent of the movement is not great because the exopod is hinged to the peduncle in a

FIG. 4.



Diagrams showing the manner of insertion of the exopod on the peduncle in the uropod of *a. Anthura gracilis*, and *b. Cyathura carinata*.

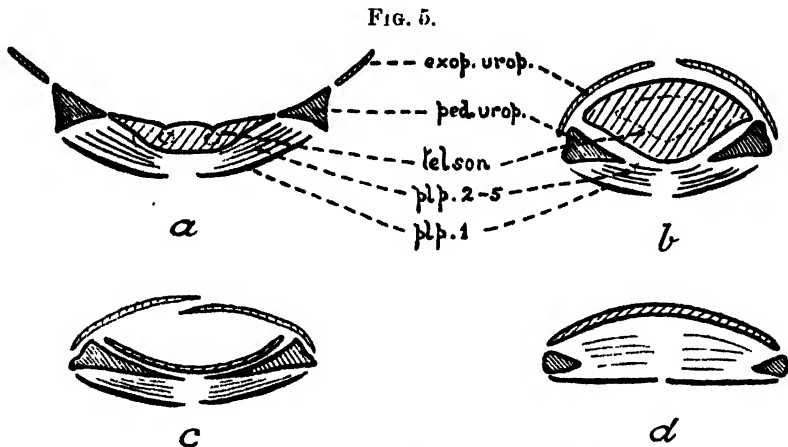
groove, the margins of which limit the movement in both directions (text-fig. 4*a*). This arrangement I have been able to confirm also in a freshly-killed specimen of *Exanthura macrura* before the muscles had become stiff.

This groove disappears posteriorly and the upper margin of the endopod, which in section is triquetral, is well developed as a sharp keel in both the species just mentioned. Against this edge the inner margin of the exopod fits closely and accurately; an additional reason for limiting the amount of movement in the hinge-joint of the exopod.

Thus the hinge-joint of the exopod, the contiguity of the opposed margins of the peduncle+endopod and exopod, and also of the outer margin of the telson and inner margin of the peduncle and endopod, all show that the position most usually assumed by the tail-fan is that of an open flat saucer-like flower (*cf.* cross-section, text-fig. 5*a*). Note that the diameter of the tail-fan is here greater than that of the animal.

Contrast with this type of tail-fan that of *Mesanthura*. The dorsal surface of the telson is here more or less convex. There is no obstacle preventing the downward folding of the exopod over the telson because the groove in which the exopod is hinged is not actually on the outer margin but a little way within it on the dorsal surface (*cf.* text-fig. 4*b*). The outer margin of the groove, however, prevents the *outward* movement of the ramus beyond a vertical position.

Moreover, there is no accurate juxtaposition of the opposed margins of the peduncle+endopod and exopod, but instead the exopod overlaps on to the outer face of the peduncle. For this purpose the outer face is hollowed out, the margin of the hollow corresponding exactly with the curve of the margin of the exopod. The most usual position for the exopods is therefore folded down over the telson, and the consequent shape of the tail-fan that of



Diagrams of transverse sections of the tail-fan in:—*a. Euxanthura macrura*; *b. Mesanthura catenula*; *c. Leptanthura laevigata*; *d. Pseudanthura lateralis*.

a flower in bud or half-open (*cf.* cross-section, text-fig. 5*b*). The inner edge of the peduncle + endopod does not meet the edge of the telson but folds under it. The diameter of the tail-fan is about the same as that of the rest of the body.

A pretty example, which may be specially mentioned, is afforded by *Haliophasma purpurea* and especially *H. tricarinata*, in which the telson is dorsally tricarinate. These keels are not developed on the basal portion, which is overlapped by the exopods, but posteriorly. The junction of these exopods leaves a  $\Lambda$ -shaped gap, and thus the median keel is developed further forward than the lateral ones (see Pl. 4, figs. 2, 3).

*Myology.*—In investigating the internal anatomy of the tail-fan some difficulty was encountered owing to the indifferent preservation of the soft parts of the specimens. No special methods were employed for preserving

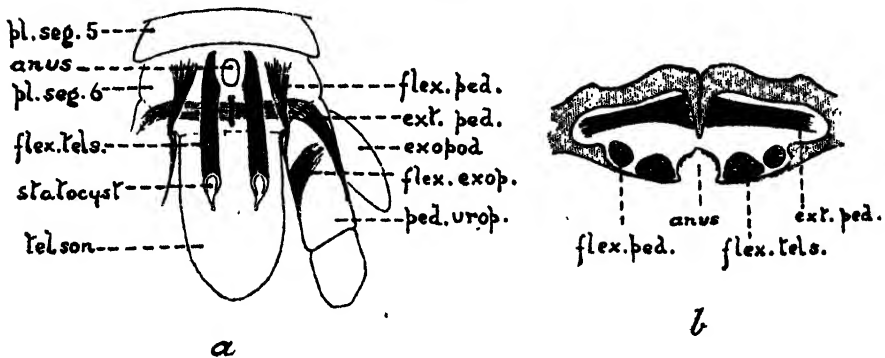
the specimens which are now in the S.A. Museum collection, and I have not been able to obtain any living specimens of a size suitable for this investigation. Nor have I been able to use the material from other Museums for this purpose.

From a large specimen of *C. carinata*, however, I have made out what appears to be the general arrangement of the muscles, and I have confirmed it in other species by means of the serial sections which were prepared for the purpose of studying the statocysts. (Text-fig. 6.)

One expects to find two sets of muscles moving each appendage, i. e. flexor and extensor muscles to the telson and to both peduncle and exopod of the uropods. The presence of all except one of these has been determined.

In the telson the flexors are the two muscles which have been noted by Thienemann and Sexton as being attached posteriorly to the anterior walls of the statocysts. Anteriorly they are attached to the ventral wall of the

FIG. 6.



Diagrams illustrating the myology of the tail-fan of *Exanthura filiformis*. a. Tail-fan viewed as a transparency from the ventral surface. b. Transverse section through the 6th pleon segment.

6th pleon segment on either side of the anus. In *Leptanthura* the muscles are attached on either side of the single statocyst to the dorsal surface of the telson, where also they are attached when there are no statocysts at all.

In *Pseudanthura* the telson is not movable on the 6th pleon segment as in most members of the family, and the flexors consequently seem to be quite degenerate.

The dorsal extensors I have not been able to find, either in cleared whole mounts or in sections. Evidently they are very small and easily decomposed, if present; perhaps the elasticity of the articular membrane between the telson and the 6th segment may render them superfluous.

The most strenuous movement of the telson is thus one of depression as compared with the axis of the body.



The flexor of the peduncle of the uropod is attached anteriorly to the antero-lateral wall of the 6th pleon segment and posteriorly to the antero-interior angle of the appendage, running nearly parallel with the flexor telsonis.

The extensor is attached posteriorly by a tendon to the outer margin of the appendage. Anteriorly it curves inwards and runs nearly transversely in the dorsal half of the 6th pleon segment to the middle line, where it is attached to a medio-longitudinal trabecula developed as an invagination of the chitinous dorsum. Sometimes the walls of the invagination are closed together, the discontinuity only showing as a mere streak in a transverse section. In other cases it remains as a comparatively large open pit, e. g. *E. filiformis*.

It is significant that in species like *A. gracilis*, in which the tail-fan appears to be normally splayed (as we have seen from a consideration of the exoskeleton alone) the flexors are not so well developed as the extensors, not even as well as they are in the other species in which the uropods are normally folded under the telson. In the former the splaying of the tail-fan is the more strenuous movement, while in the latter the two sets of muscles about balance one another.

The articulating base of the exopod possesses two small lobes to which the muscles are attached. That on the inner side, to which the flexor is attached, is a little in advance of the one outside, which serves for the attachment of the extensor. The flexor is usually stronger than the extensor, and is attached to the inner margin of the peduncle by two branches, although I have not in every case been able to find both branches. The extensor runs downwards along the outer wall of the peduncle (text-fig. 4, p. 118). In *A. gracilis*, and apparently also in the strongly indurated *E. macrura*, both muscles are feeble, the flexor more so than the extensor, and the movement of the exopod is considerably curtailed.

It will be noticed that my results do not agree entirely with those of Thienemann (1903). This author describes and figures, besides the two big muscles attached to the statocysts, narrow muscular strands connecting transversely the two statocysts and each statocyst with the external basal angle of the telson. Sexton does not mention these, and I have entirely failed to find any trace of them in sections of *A. gracilis*, *E. macrura* and *E. filiformis*, *M. catenula*, and *Apanthura* spp. This does not, of course, exclude their presence in *C. carinata*, which was the species studied by Thienemann, but the only large example of this species in my possession certainly does not show them when dehydrated and cleared in clove oil.

Thienemann further states that there are other muscles in the telson which are not connected with the statocysts, but he does not describe them. Here again, unless *C. carinata* is an exception, I cannot agree. I find no trace of any tissues other than vascular tissue posterior to the statocysts. This is so

in all the above-mentioned examples, and also in *Leptanthura* and *Accalanthura*. The vascular tissue fills up the entire interior of the telson (see text-fig. 7, d, e, f).

*Statocysts*.—We come now to one of the most interesting features of the family; for until recently it was considered unique among Isopods in possessing in the telson a structure resembling a statocyst. Since Hansen's discovery in 1916, however, this distinction must be shared with *Macrostylis*, one of the Asellota.

In the Anthuridæ these organs were first discovered by Thienemann in *Cyathura carinata*. In 1910 Stebbing recorded their presence in *C. pusilla*. Sexton (1914) described them in *A. gracilis* and refigured the telson of *C. carinata*. The only other author to note their occurrence is Hansen, who states that he found an unpaired statocyst in *Calathura brachiata*.

Although I had noted the presence or absence of these structures in the material reported on in my 1914 and 1920 papers (MSS. completed 1917, but not published until 1920), I did not refer to them as I had the present paper in view.

As regards *Calathura brachiata* Thienemann (in litt. to Sexton, 1914) denied the presence of statocysts, and at first I thought the explanation was that Thienemann was referring to *paired* statocysts, having no idea of the unpaired organ. But since examining the 'Ingolf' material I have been forced to another conclusion and can only uphold the correctness of Thienemann's observation.

Of this species I have examined nearly 100 specimens, mostly from the Copenhagen Museum, including those collected by the 'Ingolf.' In none of them can I find any trace of a statocyst.

I therefore offer the following explanation of what I believe is a *lapsus calami*. Among the 'Ingolf' material was a single specimen of a *Leptanthura*, closely allied to *tenuis*, but left unidentified by Hansen. The genus *Leptanthura* indeed was not mentioned in his report. This specimen, like all the species of this genus, possesses a very obvious statocyst, filled with crystalline particles, exactly as described by Hansen.

I believe therefore that it was this specimen, or one like it, which was examined by Hansen and on which he based his description of the statocyst and its duct, referring it through some mischance to *Calathura brachiata*, of which there are numerous specimens in the 'Ingolf' collection.

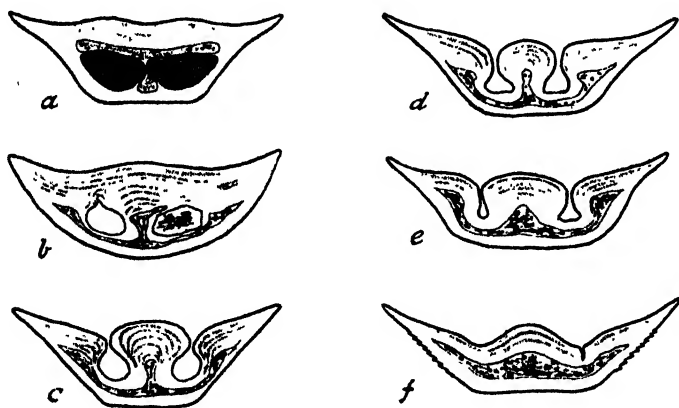
Although Sexton says that the statocysts cannot be seen in specimens preserved "in the usual way," I have been able to find them without further treatment in nearly all cases where the preservative has been formalin or spirit. Of course they show up much better after dehydrating and clearing in clove oil, and in some cases where the telson is strongly indurated, and always where sections are to be cut, preliminary treatment with acetic acid is necessary.

The family was divided into two Sections by Norman and Stebbing (1886) according to the character of the mouth-parts: Section A having normal biting mouth-parts, while Section B has these parts modified for piercing and sucking. As a result of the examination of the large amount of material I have studied, the following correlation between the mouth-parts and the statocysts has come to light: all the genera of Section A possess a pair of statocysts, the only exceptions being *Ilyssura* and *Xenanthura*, which have none; and in Section B there is either a single unpaired statocyst or none at all, never a pair of statocysts. Most of the genera in Section B have no statocyst, but it is found in *Leptanthura* and *Arcalathura*.

A brief description of the paired and unpaired organs may here be given.

*The paired statocysts* (Pl. 4. fig. 1).—In *Anthura gracilis* the telson is very thick, especially in the middle. The dorsal surface is concave with a low

FIG. 7.



Transverse sections through the 6th pleon segment and telson of *Exanthura macrura*, from camera lucida drawings. The sections were cut a trifle obliquely to the long axis, consequently figures *b*, *c*, *e*, *f* appear not quite symmetrical.

median ridge, flanked on either side by a groove. These grooves are widest and shallowest anteriorly, becoming narrower posteriorly. Communication between the vesicles of the statocysts and the exterior is afforded by a narrow tube opening into the bottom of each groove.

The statocysts are very thick-walled vesicles lying in a small mass of vascular tissue which extends backwards as a central core almost to the telsonic apex. Amorphous remains of statoliths were found in the statocysts, but no trace of hairs springing from the walls could be detected. Attached directly to their anterior walls are the muscles which depress the telson.

About in the middle of the telson on the ventro-lateral surface is a patch of minute serrulations (see text-fig. 7, *f*). I can suggest no explanation of

this feature, which is also found in *E. macrura* and *E. filiformis*, *H. tricarinata* and *H. coronicauda*, and *M. catenula*; all species with thick telsons. It is probably present in other species, but on account of its minuteness is not observable except in microtome sections.

In *E. macrura* and *E. filiformis*, and *H. tricarinata* an entirely similar arrangement is found, though the telson is not quite so thick as in *A. gracilis*. In *M. catenula* and *Ap. africana* the statocysts are of the same type, but the pores by which the tubes open do not lie at the bottom of grooves but flush with the dorsal surface.

*The unpaired statocyst.*—This structure is more remarkable than the paired structures, because the latter are so very obviously statocysts in function, though we may not be able to determine exactly what use they are to the animal; whereas the function of the unpaired structure is more difficult to explain.

It is also a little remarkable that although it was not described until 1916, it had been twice figured previously. In 1896 Bonnier shows a somewhat stellate patch in the telson of "*Calathura*" *affinis*, which certainly indicates the presence of the structure (the species is really a *Leptanthura*). In 1904 Stebbing has drawn a most exact figure of the statocyst with its duct in the telson of "*Calathura*" *sladeni*, but in his text he says "there is no appearance of statocysts such as those described by Thienemann." This shows that Stebbing was looking for *paired* structures, yet it is curious that he did not notice the true nature of the structure he has so accurately delineated. Vanhöffen (1914) half indicates the same structure in *Leptanthura lavigata*, but also has no inkling of what he or the artist was really drawing.

According to sections that I have examined of *Leptanthura lavigata* and *L. tennis*, and *Accalathura crenulata* and *A. gigas*, the statocyst is a vesicle lying near the base of the telson with a tube running posteriorly and opening on the dorsal surface by a round pore. This pore is especially large and prominent in the genus *Leptanthura*. The vesicle is usually nearly round or longitudinally oval and the walls are thick, although not so thick as those of the paired statocysts e.g. in *A. gracilis*. Amorphous aggregations of particles are frequently found in the vesicle and may represent the remains of crystalline statoliths. I have not found any hairs projecting into the lumen of the vesicle.

A noteworthy difference between the paired and unpaired structures concerns the posterior attachments of the muscles which deflex the telson. In the former these muscles are attached to the anterior walls of the statocysts, but in the latter they pass by the single vesicle and are attached to the dorsal wall of the telson. In those genera in Group B where the single vesicle is absent (e.g. *Paranthura*), these muscles are likewise attached to the dorsal wall of the telson.

The relative magnitude of the dorsal pore of the single vesicle, as compared with the minute apertures of the paired statocysts, is also noteworthy.

It seems vain to attempt any explanation of the function of this vesicle except by observations on the habits of the living animal.

As regards the origin of the statocysts, whether paired or single, and their correlation with the mouth-parts little can be said. It is reasonable to suppose, as Thienemann suggests, that the paired statocysts are invaginations of the dorsal cuticulum of the telson, due perhaps originally to the pull exerted by the depressor muscles of the telson. If, however, these muscles were originally attached at their posterior ends to the dorsal wall of the telson, as they still are in *Leptanthura*, we must explain the formation of the single vesicle as being due to some other cause. Otherwise, if we imagine the paired statocysts to have united to form a single vesicle, as we are at first naturally inclined to do, we must admit that the posterior attachment of the muscles to the dorsum of the telson (in *Leptanthura*) has been secondarily acquired. The single vesicle is thus the stumbling block to an otherwise reasonable explanation; and until the early embryonic stages both of the paired statocysts and of the unpaired vesicle are studied, we are not likely to make much headway.

## II. BIOLOGY.

It is greatly to be regretted that so little is known about the habits of the Anthuridæ. At present we even have no conclusive evidence to account for the development of suctorial mouth-parts, though we may assume that the animals of group B lead a more parasitic life than those of group A with normal mouth-parts.

The majority of specimens are obtained from encrusting material—worm-tubes, sponges, matted Hydroids and Polyzoa etc. (Stebbing 1893, Sexton 1914, and personal observations). So far as is known Anthurids have no means of constructing dwellings of their own, like certain Amphipods, unless they hollow out galleries with their mandibles. Therefore they must adopt those already made, either chance crevices among rocks or Hydroid roots, the canals in a sponge, or worm-tubes.

Very few direct observations on the habitats have been recorded. Crawshaw (quoted by Sexton 1914) records a specimen of *A. gracilis* in the tube of *Sabellaria spinulosa*, and the remarkable *Eisothistos vermiformis* was found in Serpulid tubes by Huswell, who commented on the likeness between the tail-fan and the operculum of the worm.

Bate and Westwood (1868) on the other hand seem to indicate that *A. gracilis* is mostly found attached to fishes. Though we should not definitely set aside this statement, it should be remembered that these authors were describing at the same time a *Paranthura*, one of group B with suctorial mouth-parts, and may have considered that the habits of all the species were much alike. Moreover, one must not forget Sexton's remarks on *A. gracilis*, in which the fully adult male appears to lead a more free-swimming existence than the female. Sars states (1897) that *Leptanthura tenuis* "creeps slowly along the bottom" and that he had never seen it make

any attempt to swim. Thienemann (1903) says that *C. carinata* (*A. gracilis* as he calls it) is found among encrusting barnacles etc., and that when disturbed it stretches itself out stiffly and remains in this death-feigning attitude some minutes.

To these meagre reports may be added one or two more from the South African Museum material.

The single specimen of *E. macrura* was found alive by myself in a tube of *Sabellaria capensis*, and I was able to observe how exactly the tail-fan fitted the internal diameter of the tube and was held rigidly blocking the entrance.

*H. tricarinata* was found in a bottle together with a quantity of tubes of the Polychæt *Ranzania capensis*, but no specimen was actually taken out of a tube. These tubes are composed of agglutinated sand-grains and measure 25-50 mm. in length by about 2 mm. in diameter. The diameter of the body of the Isopod corresponds very closely with that of the worm-tube. These worms being social, the Isopod might live either in the tubes themselves or in the interstices between them.

One specimen of *Paranthura punctata* was found in the central cavity of a *Leuconia*-like sponge, the diameter of which it could only just span with outstretched limbs.

Finally, *Pseudanthura lateralis* is a deep-water form living on a muddy bottom.

From these facts, as few as they are, we may distinguish three ecological groups in which structure can with fair certitude be correlated with habitat.

First, the "Sabellicolous" type as exemplified by *A. gracilis*, *E. macrura*, and *Eisothistos vermiformis*. This type is characterised by the strongly indurated telson which is wider (at least not narrower) distally than basally; by the straight lateral margins of the component parts of the tail-fan which allow them to be closely and accurately apposed; by the manner of insertion of the outer uropodal ramus so that its inward movement is restricted; and finally by the muscles being so developed that their most strenuous actions result in the *splaying* of the whole tail-fan. The outline of the tail-fan when thus splayed is quite even and the shape is subcircular or oval\*. It closes the entrance to the worm-tube, whose calibre is greater than the diameter of the animal's body.

The fact that males of *A. gracilis* have been found free-swimming does not vitiate the correlation, for it is probable that the male only becomes free-swimming after the final moult, at which the brush-like antennæ and probably also the morula-like eyes are developed. The females and immature males would still need the operculiform tail-fan as a protection to them in their more sedentary mode of life.

\* It is curious that Stebbing's two figures of plate 25 in the 1886 paper (III D ♂ and III Pl. V.) should be inaccurate in this respect. The text correctly describes the telson as equalling in length the inner uropodal ramus, but the figures show it distinctly shorter. Sexton's figure (1914) is correct.

It should be noted that this type of tail-fan and mode of life have been evolved in three separate genera.

For the second type, exemplified by such forms as the species of *Mesanthura*, *Apanthura*, *Cyathura*, etc., it is difficult to find a single descriptive name. "Tubicolous" may be used as meaning that the animals inhabit the interstices and galleries between worm-tubes as well as possibly the worm-tubes themselves. But in any case the diameter of the "home" would appear to be not very much greater than that of the animal's body.

The characteristic features are the distally tapering telson over which fold the outer uropodal rami: the outer ramus does not abut against the peduncle and inner ramus edge to edge, but overlaps on to the outer surface of the former; the peduncle and inner ramus fold under the telson; the direction of the most strenuous muscular actions of the uropods is from without inwards, so that the tail-fan becomes a deep cup no wider than the rest of the body. The tail-fan is thus not used as a defensive trap-door as in the Sabellicolous type.

The third type is represented by *Pseudanthura lateralis*, and may be termed the "Limicolous" type. This species is a deep-water one living on a fine muddy bottom. Owing to the rudimentary size of the outer uropodal rami it is scarcely correct to talk of a tail-fan; the only object of the peduncle and inner rami (fused) is to close the lateral gaps in the branchial chamber between the telson and the 1st pleopods. Strenuous muscular action is apparently not required, and consequently the muscles seem to have partly degenerated and the telson itself is immovably fused with the 6th pleon segment.

### III. CLASSIFICATION.

At the outset it should be understood that I regard the following systematic arrangement as a preliminary study only. I believe that all the admitted genera are well founded, though there are several instances of species which will not fit nicely into any genus. For these, further new genera may become necessary as our collections and our knowledge of the family increase. But it is as well to avoid a disproportionate number of monotypic genera at the start.

The system of classification is not new, but is merely an extension of that proposed by Norman and Stebbing to include the greater number of species now known.

The division of the family into two Sections, the one with biting, the other with piercing mouth-parts, is of course fundamental. Since the discovery of the remarkable correlation between the structure of the mouth-parts and of the statocysts, it is more than ever impossible to believe that the similarity of the mouth-parts is due to convergence. We cannot but regard the two Sections as being phyletically homogeneous and, as we find no transition forms, to have diverged from their common stirps at a very early date.

The delimitation of the genera within these two great Sections is a more difficult problem. To discuss their interrelations and phylogeny would be manifestly premature, seeing that future investigations are certain to discover many new forms. At present we find many genera very sharply defined, e. g. *Leptanthura* and *Mesanthura*; others again have rather indefinite boundaries owing to the policy of including a rather anomalous species in preference to making a new genus for it. On the whole the genera in Section B are more sharply defined than those in Section A.

The delimitation of the genera follows the lines laid down by Norman and Stebbing and continued by the latter author in 1900 and 1910. The 1st antennæ, maxillipeds, mandibles, peræopods, and the segmentation of the pleon provide the main features. To these have been added the pleopods and, most important of all, the shape of the telson, *i. e.* its whole shape, both when viewed from above and when seen in longitudinal and transverse section.

The following table will indicate the main differences between the Sections A and B :—

	A.	B.
Mouth-parts .....	normal.	modified.
Statocysts .....	always paired, occasionally absent.	unpaired, mostly absent.
Unguis of prp. 1 .....	long or short.	short.
Prp. 2 & 3 .....	only exceptionally subchelate or as large as prp. 1.	always similar to prp. 1.
Telson .....	sometimes splayed and indurated.	never splayed or indurated.

The following artificial key will help in identifying the genera.

#### Section A.

#### I. 5th joint prp. 4-7 not underriding 6th.

##### A. Pleopod 1 operculiform.

##### 1. Maxilliped 3-jointed.

- a.* Mandible normal ..... *Anthura*.  
*b.* " with palp 1-jointed ..... *Philanthura*.

##### 2. Maxilliped 4-jointed.

- a.* Pleon sutures distinct ..... *Euranthura*.  
*b.* " " indistinct ..... *Haliophasma*.

##### 3. Maxilliped 5-jointed.

- a.* Telson splayed ..... *Eisothistos*.

##### *b.* " not splayed.

##### i. Peræopods 2 and 3 not large.

##### *a.* Eyes present.

- \* Unguis of prp. 1 short ..... *Haliophasma*.

- \*\* " " long ..... *Malacanthura*.

##### *β.* Eyes absent ..... *Anthelura*.

- ii. Peræopods 2 and 3 large ..... *Ananthura*.



- B. Pleopod 1 not operculiform ..... *Hyssura*.
- II. 5th joint prp. 4-7 underriding 6th.
- A. Maxilliped 3-jointed ..... *Xenanthura*.
- B. „ 4-jointed ..... *Cyathura*.
- C. „ 5- or 6-jointed.
1. Pleopod 1 operculiform.
- a. Pleon sutures distinct.
- i. Maxilliped 5-jointed ..... *Apanthura*.
- ii. „ 6-jointed, with inner plate ..... *Panathura*.
- b. Pleon sutures indistinct.
- i. Antenna 1 brush-like in ♂. Body pigmented. .... *Mesanthura*.
- ii. Antenna 1 not brush-like. Body not pigmented ..... *Skuphonura*.
2. Pleopod 1 not operculiform ..... *Kupellomura*.

## Section B.

- I. With statocyst.
- A. Maxilliped 4-jointed. 5th joint prp. 4-7 not underriding 6th ..... *Accalathura*.
- B. Maxilliped 3-jointed. 5th joint prp. 4-7 underriding 6th ..... *Leptanthura*.
- II. No statocyst.
- A. Exopod of uropod not reduced.
1. 5th joint prp. 4-7 underriding 6th. Maxilliped 5-jointed ..... *Calathura*.
2. 5th joint prp. 4-7 not underriding 6th.
- a. Maxilliped 3-jointed ..... *Paranthura*.
- b. „ 2-jointed ..... *Cruregens*.
- B. Exopod of uropod reduced ..... *Pseudanthura*.
- Incertæ sedis*.
- Peræopod 7 absent ..... *Colanthura*.

## SECTION A.

Gen. ANTHURA Leach, 1814.

Eyes well developed, especially in adult ♂. Peræon segments 4-6 with dorsal pits in ♀. Pleon short in ♀, longer in ♂, the sutures distinct in ♂, not in ♀. Telson slightly concave dorsally, thick, indurated. Antenna 1 with brush-like flagellum in ♂, rudimentary in ♀. Antenna 2 with flagellum 4-6-jointed. Mandible with 1st and 3rd palpal joints subequal, the latter tipped with 2-3 feeble setæ. Maxilliped 3-jointed. Peræopod 1 very stout in ♀, 6th joint with a strong basal tooth making the hand almost chelate, in ♂ slender, 6th joint simple, unguis short. Peræopods 2 and 3 with 6th joint cylindrical. Peræopods 4-7 with 5th joint cylindrical, not underriding 6th. Pleopod 1 not indurated. Uropods indurated, exopod folding outwards. Oostegites?

Of this, the typical genus, there is now but one species, all the others having been transferred to other genera. Sexual dimorphism is well marked.

**ANTHURA GRACILIS (Mont.) 1808.**

(See also Norman & Stebbing, 1886; Sexton, 1914.)

Body dorso-laterally keeled. Telson oblong, slightly wider distally, apex truncate, crenulate, a mid-dorsal keel from base to apex, flanked by a smaller one on either side in the basal two-thirds, a deep longitudinal pit on either side of the median keel at base. (Pl. 4. fig. 1.)

Yellowish-white, with cloudy brown patches varying in size, eyes black. 11 mm.

S. England, Mediterranean. Littoral and shallow water.

I have seen a ♀ from Syracuse (Copenhagen Museum) which is indistinguishable from English specimens.

**Gen. PTILANTHURA Harger, 1878.**

Eyes developed but small (even in adult male). Peræon with dorsal pits. Pleon rather long, segments distinct. Telson? Antenna 1 with brush-like flagellum in ♂, pauciarticulate in ♀. Antenna 2 with pauciarticulate flagellum in both sexes. Mandible with palp consisting of only a single joint. Maxilliped 3-jointed. Shape of 5th joint of peræopods 4-7 and other characters uncertain.

This genus requires further elucidation. I have seen no specimens.

**PTILANTHURA TENUIS Harger, 1878.**

(See also Richardson, 1905.)

East coast of N. America, 0-19 fathoms.

**Gen. EXANTHURA Barnard, 1914.**

Eyes present. Peræon segments 4-6 with dorsal pits. Pleon segments distinct. Telson more or less dorsally concave, thick, indurated. Antenna 1 with brush-like flagellum in ♂, pauciarticulate in ♀. Antenna 2 with flagellum pauciarticulate (5-9). Mandible with 3rd palpal joint subequal to 1st, with comb of setæ. Maxilliped 4-jointed. Peræopod 1 with short sinuous palm and long unguis. Peræopods 2 and 3 with 6th joint cylindrical. Peræopods 4-7 with 5th joint not underriding 6th. Pleopod 1 indurated. Uropods indurated, exopod folding outwards. Oostegites?

This genus is closely allied to *Haliophasma*, but is distinguished mainly by the distinctly segmented pleon. The molar on the mandible is present, not obsolete as stated in my original description. The immature ♂ has the outer margin of the 1st joint of antenna 1 produced into a pointed recurved process; this seems to disappear in the fully adult ♂, and to be absent altogether in the ♀. The "ovigerous" ♀ recorded by me in 1920 was not really ovigerous, so that I am unable to state the number of oostegites.

**EXANTHURA MACRURA** Barnard, 1914.

Body dorso-laterally keeled. Pleon short. Telson long, widening distally, distal margin truncate, dorsal surface slightly concave with very low median ridge. (Text-fig. 7, p. 123.) Uropod with endopod nearly as long as peduncle, trapezoidal, apex obliquely truncate.

Whitish with brown mottling and a dark spot behind each dorsal pit. 22 mm.

S. Africa, littoral.

**EXANTHURA FILIFORMIS** (Lucas) 1849.

(See Barnard, 1920.)

Body dorso-laterally keeled. Pleon not very short. Telson not very thick, lanceolate, apex subacute, dorsal surface flat with medio-longitudinal keel from base to apex, flanked near base with a shallow groove on either side. (Pl. 4. fig. 22.) Uropod with endopod in ♂ subtriangular, longer than basal width, apex subacute, in ♀ shorter and broader, almost ovoid.

23 mm.

Algeria, Mediterranean (Lucas); S. Africa, 125–250 fathoms.

As I have seen no Mediterranean examples of Lucas's species, it remains doubtful if the S. African ones are conspecific; probably not.

**Gen. HALIOPHASMA** Hasw. 1881.

Eyes well developed. Peræon segments not or but slightly keeled dorso-laterally, with dorsal pits. Pleon short, sutures indistinct. Telson rather thick, more or less indurated and dorsally sculptured. Antenna 1 with flagellum 1–8-jointed. Antenna 2 with flagellum pauciarticulate. Mandible with 1st and 3rd palpal joints subequal, latter with comb of setæ. Maxilliped 5- (or 4-) jointed. Peræopod 1 stout, palm entire, unguis short. Peræopods 2 and 3 with 6th joint cylindrical. Peræopods 4–7 with 5th joint not under-riding 6th. Pleopod 1 more or less indurated, outer surface usually pitted or grooved. Uropods not strongly indurated, exopod folding over telson. Oostegites?

A compact and well-marked genus of four shallow-water species. The maxilliped has a characteristic stout shape, the presence of the extra suture being only of specific value. With the exception of the eyes, which are dark, pigment does not seem to be extensively developed; though I have seen no living or freshly preserved specimens.

Haswell included in his genus two species: *purpurea* and *maculata*, but without specifying either as the genotype. As *purpurea* has line precedence I have adopted it as the genotype of *Haliophasma*, transferring *maculata* to *Mesanthura*.

*HALIOPHASMA PURPUREA* Hasw. 1881.

Integument pitted. Dorsal-lateral keels feeble except on segment 1, but dorsal-lateral grooves distinct. Flagellum of antenna consisting of a single setiferous joint. Maxilliped 4-jointed. Palm of peræopod 1 almost straight and parallel to the long axis of the joint. Pleopod 1 pitted. Telson ovate-lanceolate, rather abruptly narrowed distally, apex narrowly rounded, three dorsal rounded longitudinal ridges which coalesce basally into one, a low medio-ventral ridge in apical half only. (Pl. 4. fig. 3.) Uropod with endopod not reaching telsonic apex, nearly twice as long as broad, apex narrowly rounded; exopod narrow-ovate, distally notched.

30 mm.

New South Wales (Haswell).

I have seen a ootype (♀) in the British Museum ex Australian Museum.

*HALIOPHASMA TRICARINATA*, n. sp.

Integument very feebly pitted. Dorso-lateral grooves but no keels. Flagellum of antenna 1 consisting of a single setiferous joint. Maxilliped 4-5-jointed, the basal suture across the second (free) joint being indistinct. Palm of peræopod 1 convex and transverse to long axis of joint, finely serrulate. Pleopod 1 pitted. Telson elongate-ovate, not abruptly narrowed apically, apex broadly rounded, three dorsal longitudinal rounded ridges not coalescing basally, the intervening grooves pitted, a low medio-ventral keel from apex to near base. (Pl. 4. fig. 2.) Uropod with endopod not reaching apex of telson, longer than wide, apex rounded, denticulate; exopod ovate, distally emarginate, not notched, outer margin denticulate.

15 mm.

S. Africa, 40 fathoms. (Agulhas Bank. S.S. 'Pieter Faure.' Coll. S.A. Museum.)

Very close to *purpurea*, but clearly distinguished by the band of peræopod 1 and the telson.

*HALIOPHASMA CORONICAUDA*, n. sp.

Integument not pitted. Dorso-lateral keels present but feeble. Flagellum of antenna 1 5-jointed. Maxilliped 5-jointed. Palm of peræopod 1 slightly convex. Pleopod 1 grooved. Telson ovate, apex rounded, dorsal surface with an oval raised central portion resembling the crown of a hat surrounded by a flat rim. Uropod with endopod reaching telsonic apex, longer than wide, subtrigonal with rounded apex; exopod narrow-ovate, outer margin sinuous, apex subacute.

16 mm.

S. Africa, 87 fathoms. (Off Saldanha Bay. S.S. 'Pieter Faure.' Coll. S.A. Museum.)

**HALIOPHASMA DAKARENSIS, n. sp.**

Integument not pitted. Dorso-lateral keels obsolete. Flagellum of antenna 1 8-jointed. Maxilliped 5-jointed. Palm of peræopod 1 nearly straight. Pleopod 1 grooved. Telson ovate, apex rounded, dorsal surface with two low rounded ridges at base extending as far as openings of statocysts and followed by a low angular median keel reaching apex. (Pl. 4. fig. 4.) Uropod with endopod reaching telsonic apex, broader than long, subtrigonal; exopod ovate, outer margin sinuous, apex subacute.

17 mm.

Dakar, W. Africa, 12-14 fathoms (Copenhagen Museum).

**MALACANTHURA, n. g.**

Eyes present. Peræon segments with dorsal pits. Pleon segments distinct in ♂, not in ♀. Telson not thick, nor indurated. Antenna 1 with brush-like flagellum in ♂, rudimentary in ♀. Antenna 2 with flagellum pauciarticulate. Mandible with 1st and 3rd palpal joints subequal, the latter tipped with 2-3 setæ. Maxilliped 5-jointed, resembling in shape that of *Apanthura*. Peræopod 1 stout, palm sinuous, unguis long. Peræopods 2 and 3 with 6th joint cylindrical. Peræopods 4-7 with 5th joint not underriding 6th. Pleopod 1 not indurated. Uropods not indurated, exopod folding over telson. Oostegites?

Similar to *Haliophasma*, but not indurated and with long unguis to peræopod 1.

**MALACANTHURA LINGUICAUDA (Barnard) 1920.**

Telson ovate, tapering to narrowly rounded apex, dorsal surface gently convex, ventral surface plane. Peræopod 1 with 2-3 little lobules on inner margin of finger. Endopod of uropod elongate-ovate, apex rounded.

10.5 mm.

S. Africa (Natal and Cape Point), 50-100 fathoms.

**Gen. EISOETHISTOS Hasw. 1884.**

Eyes present, but the lenses in some species few and separate. Peræon segments with dorsal pits. Pleon short or very short, but with distinct sutures. Telson dorsally flat or with a slight median ridge, not very thick, indurated. Antenna 1 with brush-like flagellum in ♂, pauciarticulate in ♀. Antenna 2 also with fewer joints in ♀ than ♂. Mandible with 1st and 3rd palpal joints subequal, latter with a small tuft of setæ. Maxilliped slender, especially in ♂, 5-jointed (a minute apical joint not counted). Peræopod 1 with 6th joint simple, cylindrical, stouter in ♀ than ♂. Peræopods 2 and 3 with 6th joint cylindrical and lower margins of 3rd and 4th joints tuberculate. Peræopods 4-7 with 5th joint triangular but not underriding 6th completely. Pleopod 1 with rami fused. Pleopods 2-5 with inner and

outer rami side by side. Uropods indurated; exopod folding inwards but not closing downwards over telson, broad with a projecting point. Oostegites?

A genus remarkable for the sexual dimorphism, especially in *vermiformis*, the pleopods and the shape of the exopod of the uropod. The generic diagnosis is based on a mutilated example of *vermiformis* and W. Indian examples of *atlanticus* which I have myself examined. Some of the above characters may therefore not be applicable to all the species.

**EISOTHISTOS VERMIFORMIS Hasw. 1884.**

Body dorso-laterally keeled. Peræopods with 2nd joint fitting closely into hollows on the sides of the body, these hollows being posterior to the insertions of the legs on the three anterior segments, anterior on the four posterior segments. Telson oblong, widening distally, distal margin truncate, crenulate, dorsal surface with a low median ridge not reaching apex.

12 mm.

New South Wales, littoral.

**EISOTHISTOS ATLANTICUS Vanh. 1914.**

Body dorso-laterally keeled, the segments hollowed laterally to receive the 2nd joints of the peræopods as in the preceding species, but here more marked in the ♂ than the ♀. Telson widening distally, distal margin truncate in ♀, slightly emarginate in ♂, strongly dentate, postero-lateral angles rounded, dentate. Uropod with inner margin of peduncle, and the whole margin of both inner and outer rami dentate, outer ramus similar in shape to that of *vermiformis*.

5 mm.

(Cape Verde Islands (Vanhöffen); St. Thomas, W. Indies, 5 fathoms (Copenhagen Museum).

The above description is taken entirely from the W. Indian specimens. I have not seen Vanhöffen's type, and consequently the identification may prove erroneous. The original description and figure are inadequate.

**EISOTHISTOS ANTARCTICUS Vanh. 1914.**

Telson apically rounded, strongly dentate, dorsal surface with a median longitudinal spinose keel. Uropods with both rami dentate.

4 mm.

Antarctic, 385 metres (Vanhöffen); 77° 5' S., 164° 17' E., 140 fathoms (Tattersall).

Original description and figure inadequate. Tattersall (1920) adds no further information. The 'Terra Nova' specimen was being studied by Tattersall when I was working at the British Museum and was not seen by me. The 5th joint of the posterior peræopods probably underrides the 6th joint to a greater extent than is represented in Vanhöffen's figure.

**Gen. ANTHELURA Norm. & Stebb. 1886.**

Eyes absent. Peræon segments without dorsal pits. Pleon segments distinct, at least laterally. Telson not indurated, moderately thick, dorsally more or less convex. Antenna 1 typically with brush-like flagellum in ♂, pauciarticulate in ♀. Antenna 2 with flagellum pauciarticulate. Mandible with 3rd palpal joint shorter than or subequal to 1st and tipped with a few setæ. Maxilliped 5-jointed, typically with well-developed inner plate. Peræopod 1 strong, palm straight, unguis long. Peræopods 2 and 3 with 6th joint more or less ovate. Peræopods 4-7 with 5th joint not underriding 6th. Pleopod 1 not indurated. Uropods not indurated, exopod folding over telson. Oostegites ?

A small but well-marked genus of rather deep-water species.

**ANTHELURA ELONGATA Norm. & Stebb. 1886.**

Mandible with 3rd palpal joint subequal to 1st, tipped with several setæ. Inner plate of maxilliped well developed. Antenna 1 with brush-like flagellum in ♂. Peræopod 1 with acutely projecting 5th joint. Peræopods 2 and 3 with 6th joint narrow-ovate, almost cylindrical. Peræopods 4-7 with 5th and 6th joints narrow. Telson lanceolate, widest in basal third, apex acute, a short and very low angular median longitudinal ridge at base, rest of dorsal surface smooth and flat. (Pl. 4. fig. 8.) Uropod with endopod narrow, more than twice as long as broad, apex subacute, exopod narrow-ovate. In the young both exopod and endopod are considerably broader.

18 mm.

Atlantic (Portuguese coast), 740 fathoms.

I have examined the type in the British Museum.

**ANTHELURA REMIPES Barnard, 1914.**

Mandible with 3rd palpal joint shorter than 1st, tipped with a few setæ. Maxilliped with well-developed inner plate. Antenna 1 with obscurely 7-jointed flagellum. Peræopod 1 similar to that of *elongata*, but palm slightly convex. Peræopods 2 and 3 with 6th joint broadly ovate. Peræopods 4-7 with 5th and 6th joints broadly expanded. Telson lanceolate, but narrowing only from distal two-thirds to subacute apex, dorsally convex. Uropod with endopod subtriangular, not more than twice as long as basal width, apex subacute, exopod ovate.

30 mm.

S. Africa, 156 fathoms.

**ANTHELURA TRUNCATA (Hansen) 1916.**

Mandible with 3rd palpal joint shorter than 1st, tipped with a few setæ. Maxilliped without inner plate. Antenna 1 with 2-jointed flagellum. Peræopod 1 with 5th joint squarely projecting, palm slightly sinuous.

Peræopods 2 and 3 with 6th joint similar to that of *elongata*. Peræopods 4-7 with 5th and 6th joints narrow. Telson broadly ovate, widest at basal third, with straight lateral margins and truncate apex, dorsal surface convex. Uropod with endopod ovate, apex rounded, exopod ovate.

10 mm.

N. Atlantic (Davis Strait), 1199-1435 fathoms.

This species clearly belongs to this genus, in my opinion ; the differences (*e.g.* the absence of inner plate on the maxilliped) seem far less important than the differences (*e.g.* number of joints in maxilliped, and shape of joints in peræopods 4-7) separating it from *Cyathura*. I can confirm Hansen's description.

For *Anthelura abyssorum* Norm. & Stæbb. and *A. affinis* Rich., see under *Ananthura*.

#### ANANTHURA, n. g.

Eyes feeble or absent. Peræon not dorso-laterally keeled, dorsal pits in one species. Pleon segments distinct. Telson lenticular in cross section, more or less thick, somewhat indurated as a rule. Antennæ 1 and 2 with pauciarticulate flagella. Mandible with 1st and 3rd palpal joints subequal, latter with comb of setæ. Maxilliped 5-jointed, with small inner plate, which may not be present in all species. Peræopod 1 with hand not greatly enlarged, palm straight, unguis short. Peræopods 2 and 3 nearly as large as peræopod 1, 6th joint slightly ovate. Peræopods 4-7 with 5th joint short but not underriding 6th. Pleopod 1 not indurated. Uropod with endopod long, subequal to peduncle, exopod closing over telson. Oostegites?

The bringing together of the three undermentioned species in this genus is not altogether satisfactory. The large size of the 2nd and 3rd peræopods, as also the elongate urepodal endopod and peræopods 4-7, seem to indicate that they are congeneric.

#### ANANTHURA SULCATICAUDA, n. sp.

Eyes absent. Peræon segments 4-6 with dorsal pits. Telson long, narrow, apex subacute, thick, especially at base, distal half rather abruptly thinner, basal half with a deep medio-longitudinal groove, moderately indurated. (Pl. 4. fig. 9.) Antenna 1 with flagellum 3-jointed. Antenna 2 with flagellum 7-jointed. Uropod with endopod apically rounded, exopod ovate, outer margin sinuate.

6.5 mm.

N. Atlantic ('Ingolf' stations 78 and 90. Copenhagen Museum).

#### ANANTHURA OVALIS, n. sp.

Eyes very faint. Peræon without dorsal pits. Telson ovate-lanceolate, apex subacute, not very thick, dorsal surface smooth, gently convex, with a



longitudinal pit near base. (Pl. 4. fig. 10.) Antenna 1 with flagellum 3-jointed. Antenna 2 with flagellum 7-jointed. Uropod with endopod apically rounded; exopod broadly ovate, outer margin distally serrulate.

5.5 mm.

Mediterranean, Syracuse (Copenhagen Museum).

*ANANTHURA ABYSSORUM* (Norm. & Stebb.) 1886.

This species does not belong to *Anthelura*, and is probably to be associated with the two preceding species.

I am unable to add any details to the original description, which was in many points inadequate, *e. g.*, the shape of the telson and uropodal rami. The type in the British Museum lacks both head and tail-fan. Dr. Calman informs me that there is a more perfect specimen in the Norman collection, now in the British Museum; this specimen unfortunately I did not see.

9 mm.

N. Atlantic, 1750 fathoms.

*Anthelura affinis* Rich. 1902, may also belong to this genus, but the description and figure are inadequate.

Genus *HYSSURA* Norm. & Stebb. 1886.

Body elongate. Eyes absent. Peræon not dorso-laterally keeled, without dorsal pits. Pleon elongate, segments distinct. Telson elongate, narrow, pointed, more or less thick and indurated, without statocysts. Antennæ 1 and 2 with pauciarticulate flagella. Mandible with 3rd palpal joint subequal to 1st, with comb of setæ. Maxilliped 5-jointed, with inner plate. Peræopod 1 with 6th joint ovate, palm straight, unguis short. Peræopods 2 and 3 at least equal in size to 1st, and similar in shape. Peræopods 4-6 with 5th joint cylindrical, not overriding 6th. Segment 7 without peræopods. Pleopod 1 not operculiform, not larger than others, both rami equally developed. Uropods with rami more or less narrow, exopod hinged transversely and folding down over telson. Oostegites?

Although I have seen the type of *H. producta* in the British Museum, I have only been able to investigate the mouth-parts in the Paris Museum specimen of the n. sp. *H. profunda*. The generic diagnosis may therefore have to be altered later. Thus Norman and Stebbing say that the maxilliped in *producta* is 5-jointed *exclusive of the basal joint*.

*HYSSURA PRODUCTA* Norm. & Stebb. 1886.

Telson very narrow, circular in cross section. Endopod of uropod terete, longer than peduncle; exopod very narrow, terete. (Pl. 4. fig. 16.) Peræopods 4-6 with 4th to 6th joints twice as long as broad.

6.5 mm.

N. Atlantic, 56° 11' N., 37° 41' W., 1450 fathoms.

*HYSSURA PROFUNDA*, n. sp.

Telson narrow-lanceolate, lateral margins evenly converging to the acute apex, lenticular in cross section, being more convex dorsally than ventrally. Endopod of uropod narrow, elongate, flattened, dorsally concave, longer than peduncle; exopod narrow-ovate, apex narrowly rounded, flattened, concave ventrally (i. e. when folded down over telson). (Pl. 4. fig. 17.) Peræopods 4-6 with 4th-6th joints broad, not more than half as long again as broad, oar-like.

10 mm.

'Travailleur' Collection, No. 50, 13.7.81 (Paris Museum).

This specimen had been previously determined as *producta* by Miss Richardson.

"*Hyssura*" *spinicauda* Walker 1901, does not belong to this genus, see p. 147.

*XENANTHURA*, n. g.

Eyes present. Peræon not dorso-laterally keeled, without dorsal pits. Pleon long, segments distinct. Telson greatly reduced, thin, without statocysts. Antenna 1 with flagellum brush-like in ♂, single-jointed in ♀. Antenna 2 with flagellum reduced to 3-4 obscurely separated joints, a minute two-jointed secondary flagellum (exopod) on outer apex of last (fourth) peduncular joint. Mandible with palp represented by a seta only. Maxillipeds 3-jointed, the 2nd joints fused, apical joint triangular. Peræopod 1 with straight palm, unguis short. Peræopods 2 and 3 also subchelate but a little smaller than peræopod 1, 6th joint ovate. Peræopods 4-7 very short, 5th joint underriding 6th. Pleopod 1 not operculiform, no larger than the others, both rami equally developed. Uropods with endopod completely fused with peduncle; exopod large, ovate, closing down over its fellow and over the telson. Oostegites?

The number of unusual features in this genus has suggested the generic name.

*XENANTHURA BREVITELSON*, n. sp.

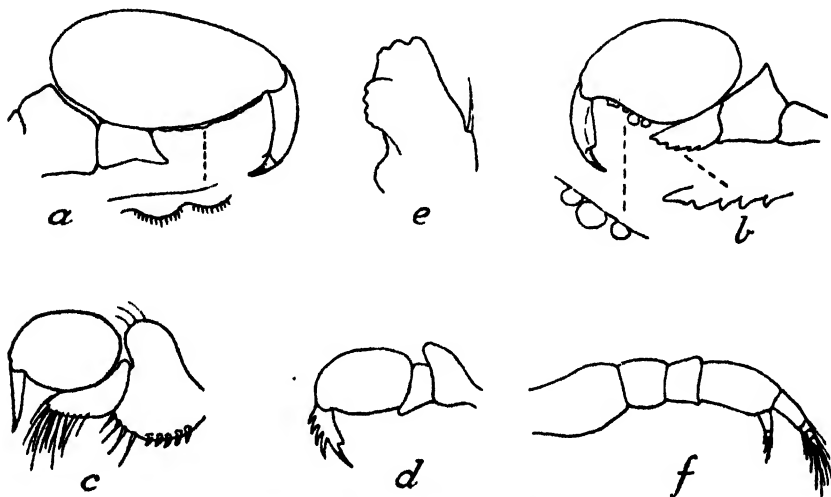
Eyes in adult ♂ divided into three groups, each with a few lenses, along lateral margin of head. Head rounded (♂) or subrotund (♀), rostrum unusually prominent. Telson very short, oblong, apically truncate, with 3-4 long setæ. Peræopod 1 with 5th joint acutely projecting, 6th ovate, palm straight. Peræopod 2 only a little smaller, 5th joint produced in an acute apex, inferior margin serrate, 6th broadly ovate, palm convex. Peræopod 3 a little smaller than 2, 4th joint broadly triangular, inferior margin spinulose, 5th joint subacutely produced with tuft of long setæ, 6th broadly ovate, palm very short, finger straight. Peræopods 4-7 not as long as their

segments, 6th joint ovate, 7th serrate on outer margin. Uropod with fused peduncle and endopod oblong, inner margin straight, apposed to that of its fellow, distal margin obliquely subtruncate; exopod broadly oval, almost circular. (Pl. 4. fig. 14 and text-fig. 8.)

White, eyes dark. 4 mm.

St. Thomas, W. Indies, 25-30 fathoms (Copenhagen Museum).

FIG. 8.



*Xenanthura brevitelson*, n. g. et sp.

a. Peræopod 1; b. peræopod 2; c. peræopod 3; d. peræopod 6; e. mandible; f. antenna 2.

#### Gen. CYATHURA Norm. & Stebb. 1886.

Eyes typically present, sometimes absent. Peræon typically with dorso-lateral keels and dorsal pits. Pleon with sutures indistinct dorsally. Telson lenticular in cross-section, thin, smooth. Antenna 1 with flagellum 1-3-jointed, sometimes brush-like in ♂. Antenna 2 with flagellum of a single joint. Mandible with 3rd palpal joint usually larger than 1st, with rather large apical tuft of setæ. Maxilliped 4-jointed. Peræopod 1 with more or less pronounced tooth on palm of 6th joint, unguis typically long. Peræopods 2 and 3 with 6th joint cylindrical. Peræopods 4-7 with 5th joint underriding 6th. Pleopod 1 not indurated. Uropods not indurated, exopod folding over telson. Oostegites 3 pairs (in *siamensis* and also, *apud* Harger, in "*Anthura polita*" = *C. carinata*).

Besides the genotype, *C. carinata*, four other species are here included in this genus, although they differ in certain respects. In two small species the eyes are absent and in two others the males have brush-like upper antennæ. Eventually perhaps these will be removed to another genus.

**CYATHURA CARINATA (Kröyer) 1847.**

(See also Norman & Stebbing, 1886. Synonyms: Richardson, 1905; also syn. *C. estuarius* Barnard, 1914).

Eyes present. Peræon distinctly keeled dorso-laterally, with pits. Antenna 1 with 3-jointed flagellum. Mandibular palp large in proportion to trunk. Peræopod 1 with apex of 5th joint subacutely projecting, palm with a tooth near base, unguis long. Peræopods 2 and 3 with 6th joint cylindrical. Telson ovate, sides straight, gradually converging to the rounded apex, slightly convex dorsally. Uropod with endopod about as broad as long, outer and distal margins distinct, apex rounded, exopod ovate. ♂ stylet on pleopod 2 apically complex.

Whitish, with brown mottling (S. African specimens). 13–27 mm.

Europe, N. America, S. Africa; China (Tattersall).

Frequently found in brackish or quite fresh water.

**CYATHURA PUSILLA Stebb. 1904 b & 1910.**

Eyes absent. Peræopod 1 with 5th joint not projecting, palm sinuous, unguis short. Telson ovate, apex rounded. Uropod with endopod longer than broad, ovoid, outer and distal margins confluent, apex rounded.

7.5 mm.

Ceylon and British East Africa (Stebbing).

Description taken from Stebbing; I have seen no specimens.

**CYATHURA SIAMENSIS, n. sp.**

Eyes absent. Peræon not dorso-laterally keeled. Antenna 1 with flagellum of a single joint. Peræopod 1 with 5th joint rounded-triangular, not projecting, 6th joint somewhat transversely oval, palm short and strongly convex, unguis short. Peræopods 2 and 3 similar but smaller, 6th joint longitudinally oval. Telson lanceolate, widest in middle, the lateral margins proximal and distal to the widest part straight. (Pl. 4. fig. 6.) Uropod with endopod triangular, longer than broad, margin nearly straight between outer basal angle and subacute apex; exopod narrow-ovate, apex subacute.

6 mm.

Siam, 3–5 fathoms (Copenhagen Museum).

Easily distinguished by the shape of the telson and uropods.

**CYATHURA INDICA, n. sp.**

Eyes present. Peræon not strongly keeled dorso-laterally. Antenna 1 with brush-like flagellum in ♂, obscurely 3-jointed in ♀. Mandibular palp not large. Peræopod 1 with 5th joint not projecting, palm straight with basal tooth, unguis long. Telson linguiform, lateral margins parallel, apex rounded, dorsal surface flat, ventral with low medio-longitudinal ridge.

(Pl. 4. fig. 7.) Uropod with endopod similar to that of *carinata*, a trifle broader in ♀ than ♂, exopod ovate. ♂ stylet on pleopod 2 apically simple. 3.5–8 mm.

Singapore, Siam, and Paumben, Adam's Bridge, Ceylon, 1–14 fathoms (Copenhagen Museum).

*CYATHURA CRUCIS*, n. sp.

Eyes present, large. Peræon not dorso-laterally keeled. Antenna 1 with brush-like flagellum in ♂. Peræopod 1 with 5th joint not projecting, palm with tooth near base, unguis long. Peræopods 2 and 3 with 6th joint cylindrical. Telson linguiform, apically broadly rounded, very thin, nearly flat both dorsally and ventrally. (Pl. 4. fig. 5.) Uropod with endopod similar to that of *carinata*, exopod ovate. ♂ stylet on pleopod 2 apically simple.

7 mm.

St. Croix, W. Indies, 4 fathoms (Copenhagen Museum).

The last two species are distinguished from the typical *C. carinata* by the brush-like 1st antenna. They may later be transferred to another genus.

Gen. *APANTHURA* Stebb. 1900.

Eyes usually present, absent in the deeper water species. Peræon segments not pitted. Pleon with the sutures distinct. Telson not indurated, rather thin, dorsally smooth and convex. Antenna 1 with flagellum of 1 joint or obscurely 2–3-jointed, or occasionally brush-like in ♂. Antenna 2 with flagellum rudimentary. Mandible with 3rd palpal joint shorter than or subequal to 1st, sometimes with a comb of setæ, sometimes with only an apical tuft. Maxilliped 5-jointed. Peræopod 1 usually with a tooth on palm near base, unguis typically long. Peræopods 2 and 3 with 6th joint somewhat ovate. Peræopods 4–7 with 5th joint underriding 6th. Pleopod 1 not indurated. Uropods not indurated, exopod folding over telson. Oostegites 4 pairs (*A. xenocheir*, *apud* Stebbing).

Stebbing shows a minute inner plate in the maxilliped of *A. sandalensis*, but I have not observed this in any specimens belonging to species which I consider really belong to this genus. One species, *A. xenocheir*, has an anomalous hand to the 1st peræopod.

*APANTHURA SANDALENSIS* Stebb. 1900.

(Syn. *A. dubia* Barnard, 1914.)

Eyes present. Antenna 1 with 3-jointed flagellum. Mandible with 3rd palpal joint shorter than 1st, tipped with a few setæ. Peræopod 1 with or without a basal tooth on palm. Telson ovate, apex rounded, setose, dorsal surface feebly convex. Uropod with endopod nearly twice as long as broad, exopod broadly ovate, apex notched.

Yellowish-white mottled with greyish specks, eyes black. 10 mm.

Loyalty Islands; S. Africa, littoral.

I have seen the type and a cotype of *A. sandalensis* in the British Museum, and have satisfied myself that *A. dubia* is a synonym. The cotype has a tooth on the palm exactly as represented in my figure of *A. dubia*.

**APANTHURA XENOCHEIR Stebb. 1910.**

Eyes present. Antenna 1 with obscurely 3-jointed flagellum. Mandible with 3rd palpal joint subequal to 1st, with short comb of setæ. Peræopod 1 with lower margin of hand produced into a tooth, a small cavity between this and base of finger into which the short curved finger closes. Telson ovate, apex rounded. Uropod with endopod not much longer than broad, subcircular, exopod ovate.

Apparently pale with darker speckling. 5 mm.

Egmont Reef, Seychelle Islands, littoral.

Description taken from Stebbing; I have seen no specimens.

**APANTHURA AFRICANA Barnard, 1914.**

Eyes absent. Antenna 1 with 3-jointed flagellum. Mandible with 3rd palpal joint shorter than 1st, with apical tuft. Peræopod 1 with 5th joint acutely produced, palm excavate distally, unguis rather short. Telson lanceolate, apex acute, dorsally rather strongly convex. Uropod with endopod narrow-triangular, apex acute, exopod ovate.

17 mm.

S. Africa, 80 fathoms.

**APANTHURA COPPINGERI, n. sp.**

(Syn. *Paranthura australis* Miers, 1884, and Haswell, 1885, *sed non* Haswell, 1881.)

Eyes absent. Antenna 1 with flagellum of a single joint. Mandible with 3rd palpal joint subequal to 1st, with apical tuft. Peræopod 1 with 6th joint rather elongate-ovate, palm with blunt tooth near base. Peræopods 2 and 3 with 5th joint narrow but long, with prominently projecting blunt inferior apex. Peræopods 4-7 with 5th joint prominently projecting at lower apex, 6th joint slender. Telson lanceolate, widest across the middle, apex subacute, dorsally moderately convex. (Pl. 4. fig. 12.) Uropod with endopod considerably narrower than peduncle, cylindrical, slightly curved inwards, apex narrowly rounded, exopod ovate.

13 mm.

Dundas Straits, 17 fathoms (coll. Dr. Coppinger, H.M.S. 'Alert,' Brit. Museum).

Miers had doubts as to this being the *P. australis* of Haswell. The endopod of the uropod is distinctive.

*APANTHURA SENEGALENSIS*, n. sp.

Eyes very large. Antenna 1 with flagellum brush-like. Mandible with 3rd palpal joint shorter than 1st, with comb of setæ. Peræopod 1 with 5th joint squarely produced, palm abruptly excavate distally. Peræopods 4-7 with 6th joint abruptly narrower than 5th. Telson rather broadly ovate, apex subacute, dorsally feebly convex. (Pl. 4. fig. 11.) Uropod with endopod rather narrow, apex narrowly rounded, exopod ovate.

7 mm.

Dakar, 5 fathoms (Copenhagen Museum).

The brush-like 1st antenna is exceptional in this genus, but all the other characters indicate that this species is nearest to *Apanthura*.

*PANATHURA*, n. g.

Similar to *Apanthura*, but maxilliped 6-jointed with well-developed inner plate, and palm of peræopod 1 straight. Unguis long.

*PANATHURA SERRICAUDA* (Barnard) 1920.

Eyes small. Antenna 1 with flagellum 2-jointed. Mandible with 3rd palpal joint shorter than 1st. Telson obovate, widest at distal two-thirds, apex broadly rounded, serrate. Uropod with endopod as long as broad, distally rounded, serrate; exopod broadly oval, margin serrate.

Uniform yellowish-white, eyes black. 5 mm.

S. Africa, littoral.

(Gen. *MESANTHURA* Barnard, 1914.

Eyes present. Peræon without dorsal pits. Pleon short, sutures absent or extremely obscure. Telson not indurated, dorsally smooth, convex or sometimes nearly flat. Antenna 1 with flagellum brush-like in ♂, 2-jointed in ♀. Antenna 2 with flagellum 2-4-jointed. Mandible with 3rd palpal joint as long as or longer than 1st, with comb of setæ. Maxilliped 5-jointed, the narrow waist-like 3rd (2nd free) joint being very characteristic. Peræopod 1 with palm of 6th joint distally excavate, unguis long. Peræopods 2 and 3 with 6th joint cylindrical. Peræopods 4-7 with 5th joint underriding 6th. Pleopod 1 not indurated. Uropods not indurated; exopod apically notched, folding down over telson. Oostegites 4 pairs.

This genus is very well defined both structurally and by the extensive development of pigment to form a pattern which is characteristic of each species. The diagrams will give a better idea of these patterns than words. Structural features separating the species are hard to find. All the species are dwellers in the littoral or shallow water.

*MESANTHURA CATENULA* (Stimpson) 1855.

(See also Beddard, 1886, and Barnard, 1914.)

Mandibular palp strong in proportion to the trunk. Telson with slightly

sinuous lateral margins, apex rounded, setose, dorsally strongly convex. Markings, text-fig. 9a.

20 mm.

S. Africa, littoral.

*MESANTHURA MACULATA* (Hasw.) 1881.

(Syn. *Anthura affinis* Chilton, 1883.)

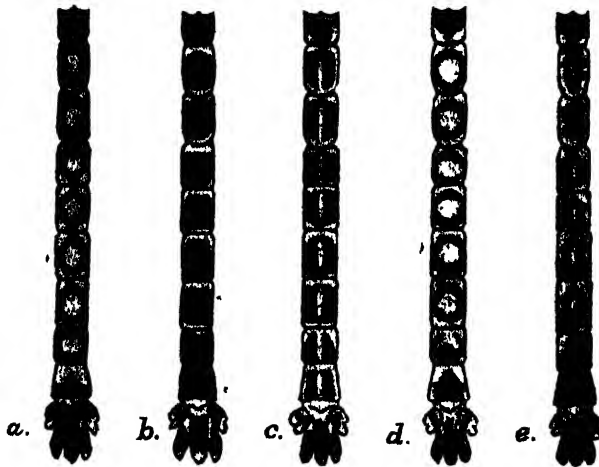
Mandibular palp not unusually strong. Telson similar to that of *M. catenula* but not so convex dorsally. Markings, text-fig. 9b.

14 mm.

New South Wales, New Zealand, 0-52 fathoms.

I have seen four examples of *M. maculata* from the type locality, and two of Chilton's cotypes of *A. affinis*.

FIG. 9.



Semidiagrammatic drawings of the species of *Mesanthura* to show colour pattern.

a. *M. catenula*; b. *M. maculata*; c. *M. albolineata*; d. *M. ocellata*; e. *M. pulchra*.

*MESANTHURA OCELLATA*, n. sp.

Mandibular palp with 3rd joint not so strongly developed as in the two preceding species. Telson dorsally almost flat, ventrally slightly convex. Markings, text-fig. 9d.

13 mm.

Siam, 1 fathom (Copenhagen Museum).

*MESANTHURA ALBOLINEATA*, n. sp.

Mandibular palp as in *M. ocellata*. Telson dorsally almost flat, ventrally slightly convex. Markings, text-fig. 9c.

12 mm.

Singapore (Copenhagen Museum).



**MESANTHURA PULCHRA**, n. sp.

Mandibular palp as in *M. ocellata*. Telson dorsally almost flat, ventrally slightly convex. Markings, text-fig. 9*e*.

7 mm.

St. Thomas and St. John, W. Indies, 10–18 fathoms (Copenhagen Museum).

*Paranthura miersi* Hasw. 1885. This species seems to me to be undoubtedly a *Mesanthura*—cf. the description and figures of the antennæ and the 1st and posterior peræopods, especially the hand of peræopod 1. I would even suggest that it is specifically identical with *M. maculata*, though it certainly seems strange that Haswell, when describing *M. miersi* as having each segment “marked with a large patch of blackish purple,” could have forgotten that *M. maculata*, described by him four years earlier, possessed the same striking coloration. Both species were originally described from Port Jackson, which adds to the probability of their being synonymous.

**SKUPHONURA**, n. g.

Eyes present. Peraeon not keeled dorso-laterally, without dorsal pits. Pleon segments 1–5 completely fused without trace of sutures, wider than peræon and with postero-lateral angles of segment 5 produced backwards; pleon segment 6 much narrower than preceding segments, narrower even than peræon. Telson not indurated, dorsally convex, smooth, ventrally concave. Antenna 1 with flagellum of a single joint. Antenna 2 with flagellum of a single joint. Mandible with 3rd palpal joint shorter than 1st, tipped with a few setæ. Maxilliped 5-jointed. Peræopod 1 stout, palm sinuous, unguis short. Peræopods 2 and 3 much more slender, 6th joint narrow ovate. Peræopods 4–7 with 5th joint underriding 6th. Pleopod 1 not indurated. Uropods not indurated; exopod not folding down over, but nearly vertical at sides of telson. Oostegites?

**SKUPHONURA LATICEPS**, n. sp.

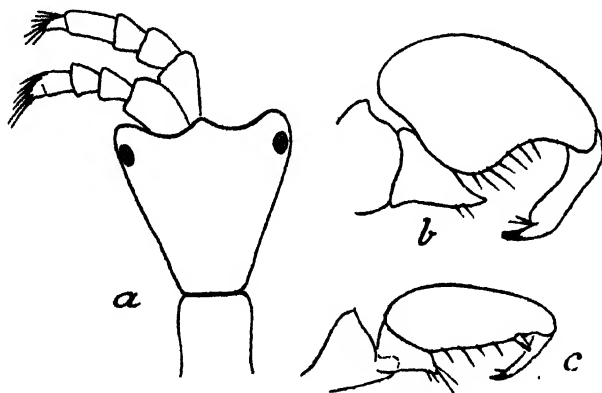
Eyes small. Head enlarged, subtriangular, frontal width subequal to length, antero-lateral angles rounded. In young, head less expanded, longer than broad, antero-lateral angles acute. Strongly keeled ventrally behind maxillipeds. Peraeon segment 1 with a medio-ventral forwardly directed strong spine. Telson ovate, apex subacute, setose. Antennæ 1 and 2 stout and shorter than head in adult ♂, flagellum of antenna 1 with apical brush of setæ. Peræopod 1 with 5th joint acutely produced at lower apex, 6th joint broadly ovate with sinuous palm, unguis considerably narrower than finger. Pleopod 2 with ♂ stylet arising near base, extending beyond ramus, apex simple. Uropod with endopod narrow, twice as long as broad, apex subacute, outer margin setose; exopod apically notched, crenulate and setose. (Pl. 4. fig. 15 and text-fig. 10.)

7 mm.

St. Thomas, St. John, St. Croix, and Tobago, W. Indies, 4-20 fathoms (Copenhagen Museum).

This species is remarkable for the expanded head, the pleon, and the flagella of both antennæ.

FIG. 10.



*Skuphonura laticeps*, n. g. et sp.

a. Head and antennæ ♂; b. peræopod 1; c. peræopod 2.

#### KUPELLONURA, n. g.

Eyes present, enlarged in ♂. Peræon not dorso-laterally keeled, without dorsal pits. Pleon elongate, segments distinct. Telson shorter than pleon, thin, dorsally flat, not indurated, statocysts small. Antenna 1 with brush-like flagellum in ♂. Antenna 2 with 8-jointed flagellum. Maxilliped 5-jointed, narrow. Peræopod 1 with straight palm, unguis short. Peræopods 2 and 3 with 5th joint acutely projecting inferiorly, 6th joint ovate. Peræopods 4-7 with 5th joint underriding 6th. Pleopod 1 not operculiform, not larger than the others, both rami equally developed. Uropods not indurated, exopod large, hinged transversely and folding down over telson. Oostegites?

#### KUPELLONURA MEDITERRANEA, n. sp.

Body slender. Pleon segments 1-6 nearly equal to last 3 peræon segments together. Telson ovate, apex excised on either side of a small median setulose lobe, dorsal surface flat, ventral slightly convex. (Pl. 4. fig. 13.) ♂ stylet on pleopod 2 reaching beyond apex of ramus, apex uncinat. Uropod with endopod as long as peduncle, reaching telsonic apex, narrow, apically subacute; exopod large, lanceolate, rapidly narrowing from base to acute setose apex which reaches to or nearly to telsonic apex.

White, eyes reddish. 5 mm.

Messina (Copenhagen Museum).

*Species inquirenda.*

"HYSSURA" SPINICAUDA Walker, 1901.

This species obviously does not belong to *Hyssura*. The 1st and 2nd peræopods are closely similar to those found in *Xenanthura*, with which the fused peduncle and endopod of the uropod also agree, if Walker's figure is to be trusted in this point. The 7th segment is stated to possess peræopods, which it does not in *Hyssura*.

I have seen both the type (mounted on a slide) and a cotype in the British Museum, but did not venture to investigate the mouth-parts of the latter. There appear to be no statocysts in the mounted type.

## SECTION B.

## ACCALATHURA, n. g.

Eyes present (with one exception). Peræon segments not strongly keeled dorso-laterally, without dorsal pits but usually with an impressed transverse line on anterior margin of segments 4-9; segment 7 short. Pleon not elongate, sutures distinct. Telson longer than pleon, dorsally convex, flat or even slightly concave, thin, not indurated, with a single basal statocyst opening by a dorsal pore. Antennæ 1 and 2 with multiarticulate flagella in both sexes, in ♂ bearing whorls of short setæ. Mandible with 3rd palpal joint subequal to 1st, with comb of setæ, 2nd joint not greatly longer than others. Maxilliped 4-jointed, the "palp" usually extending slightly beyond the inner projection of 2nd joint. Peræopod 1 with palm straight with basal tooth, unguis short. Peræopods 4-7 with 5th joint cylindrical, as long as 4th and not underriding 6th. Pleopod 1 not indurated. Uropods with endopod distinctly narrower than peduncle; exopod as a rule narrow, folding over telson. Oostegites 3 pairs.

It has been found necessary to institute this genus for the species *A. crenulata* (Rich.), *A. borradalei* (Stebb.), and *A. gigas* (Whitel.), formerly placed in the genus *Calathura*, from the genotype of which they are essentially different. To these species I have added another, which, though disagreeing in some points, nevertheless fits better here than anywhere else. Eventually a separate genus may become necessary.

## ACCALATHURA CRENULATA (Rich.) 1901.

Postero-lateral angles of peræon segment 7 produced backwards and embracing pleon segments 1 and 2. Telson ovate, apex narrowly rounded, crenulate and setose, dorsally slightly convex, a short low median ridge at base above the statocyst, succeeded beyond the dorsal pore by a very shallow median groove. (Pl. 4. fig. 18.) Endopod of uropod subquadrate, distinctly longer than broad, outer and inner margins subparallel; exopod narrow-lanceolate, outer margin slightly sinuous, apex acute. Peræopods slender

Yellowish with darker speckling, eyes dark. 18 mm.

Tropical Atlantic, 5-40 fathoms, Bahamas, Yucatan, Brazil; Danish West Indies (Copenhagen Museum); Cape Verdes ('Talisman' coll. Paris Museum).

The telsonic characters given above are taken from the 'Talisman' specimens in the Paris Museum, which were identified by Miss Richardson. I have also seen one of the 'Albatross' specimens from the coast of Brazil but not the types. The large Danish specimens are in essential agreement with the 'Talisman' specimens, but possess a basal tooth on the palm of peræopod 2 while lacking one on that of peræopod 1. In the 'Talisman' specimens the reverse is the case, but as these latter are all males whereas the sex of the former is uncertain, it may be a case of sexual dimorphism. The smaller Danish specimens on the other hand do not differ in any way from the Cape Verde specimens.

*ACCALATHURA GIGAS* (Whitel.) 1901.

(Syn. *C. sladeni* Stebb. 1910.)

Very close to *crenulata*. Postero-lateral angles of peræon segment 7 produced backwards. Telson ovate, similar to that of *crenulata*, dorsally slightly convex with a low rounded hump above the statocyst. Endopod of uropod narrower than in *crenulata*, but not so narrow as in Whitelegge's figure; exopod narrow-lanceolate, outer margin sinuous, apex acute. Peræopods slender. Oostegites 3 pairs.

42 mm.

New South Wales, 36-39 fathoms (Whitelegge); Gulf of St. Vincent (Adelaide Museum); Seychelles (Stebbing; *C. sladeni*).

Although I have not seen Whitelegge's type, I cannot but assign the Adelaide Museum specimens to this species. They differ only in having well-marked pigmented eyes and a slightly wider endopod to the uropod. Neither of these points is an insuperable difficulty. The eye pigment in Whitelegge's specimens may have been bleached by the preservative, though it is true that as a rule black ocular pigment is fast. The marked narrowness of the uropodal endopod in Whitelegge's figure may be due to the appendage having been observed in a slightly oblique position by the artist. Or this joint may become narrower in very large specimens like the types, though the smaller specimens I have seen were fully adult. In the Adelaide specimens the inner margin of endopod and peduncle of uropod, apex of endopod and telson, both margins of the exopod, and the palm of the anterior peræopods are thickly clothed with long plumose setæ, which may have become worn away in Whitelegge's specimens.

Now comes the further question whether Stebbing's *C. sladeni* is not a synonym of *A. gigas*. Stebbing's description and figures fit in admirably with the Adelaide specimens, even to the hairs on the antero- and postero-

lateral angles of the segments. The telson, however, in *sladeni* is slightly more acute at the apex. Nevertheless, I do not think anyone would hesitate to identify the S. Australian specimens with Stebbing's species.

Therefore, if the identity of the S. Australian specimens with Whitelegge's *gigas* is well founded, *sladeni* must become a synonym. If not we must admit the occurrence of a smaller eyed form (*sladeni*) common to the Seychelles and S. Australia which is replaced on the east coast of Australia by a larger blind form (*gigas*).

The question of the eyes is really the crux of the matter. The relative sizes do not matter so much, as considerable variation in this respect is known among other species. Stebbing's ♂ with stylet on pleopod 2 was 10 mm. long; the Adelaide Museum has an adult ♂ and an ovigerous ♀ 18 mm., and two others not quite mature 25 mm. long. Whitelegge's specimens measured 42 mm.

*ACCALATHURA BORRADALEI* (Stebb.) 1904 *a*.

Postero-lateral angles of peræon segment 7 scarcely produced backwards. Telson ovate, apex rounded or somewhat pointed, setose, dorsally slightly convex. Uropod with endopod subovate, slightly longer than broad, outer margin merged in distal margin; exopod narrow-ovate, outer margin sinuous, apex subacute. Peræopods slender.

10 mm.

Maldivé Archipelago, 23 fathoms (Stebbing); Siam, 15 fathoms (Copenhagen Museum).

I have not seen Stebbing's type, but I can perceive no differences in the Siam specimens except that the telsonic apex is rather more pointed than in Stebbing's figure.

*ACCALATHURA CRASSA*, n. sp.

Body stout. Eyes absent. Postero-lateral angles of peræon segment 7 not produced. Telson nearly parallel-sided, apically broadly rounded, dorsally nearly flat. Flagella of both antennæ rudimentary. Inner plate of maxilliped smaller than in typical *Accalathura*.

8 mm.

St. John, West Indies (Copenhagen Museum).

This species will probably be transferred to another genus eventually, owing to the several differences noted above.

Gen. *LEPTANTHURA* Sars, 1897.

Eyes absent (or feebly pigmented specks which fade in preservatives). Peræon feebly keeled dorso-laterally, no dorsal pits. Pleon elongate, sutures distinct. Telson shorter than pleon, concave dorsally, thin, not indurated, with a single statocyst opening by a dorsal pore near base. Antenna 1 with

brush-like flagellum in ♂, rudimentary in ♀. Antenna 2 with rudimentary flagellum in both sexes. Mandible with 3rd palpal joint shorter than 1st, with 2 apical setæ, 2nd considerably longer than others. Maxilliped 3-jointed, 2nd joint much the longest. Peræopods 1-3 with concave palm with basal projection, unguis short. Peræopods 4-7 with 5th joint under-riding 6th. Pleopod 1 not indurated. Uropods with endopod almost as broad as peduncle; exopod broadly oval, meeting in middle line and folding down over telson. Oostegites 3-4 pairs.

This clearly defined genus ranges over the greater part of the world. The species are mostly inhabitants of deep water and appear to be white or colourless. Beyond Sars's observations on *L. tenuis* nothing is known of the habits.

*LEPTANTHURA TENUIS* (Sars) 1872.

Telson nearly parallel-sided, apex pointed, with a small tuft of setæ. Exopod of uropod broadly ovate with nearly straight outer margin; endopod elongate, at least twice as long as broad. Four pairs of oostegites.

14 mm.

N. Atlantic, 150-718 fathoms.

*LEPTANTHURA AFFINIS* (Bonnier) 1896.

Very close to and in all probability really identical with *L. tenuis*; but according to Bonnier's figure distinguished by the lanceolate telson, widening from the base to the middle, whereas in *L. tenuis* the sides are approximately parallel. I have not seen the type.

Gulf of Gascony, 1410 metres.

*LEPTANTHURA GLACIALIS*, Hodgson, 1910.

The two type specimens which I have seen in the British Museum seem indistinguishable from *L. tenuis* except by their larger size and slightly shorter endopod of the uropod. The ovigerous ♀, however, has only three pairs of oostegites.

17 mm. (the larger of Hodgson's two specimens).

Antarctic, 25-250 fathoms.

*LEPTANTHURA ORIENTALIS*, n. sp.

Telson widest at base, narrowing slightly to the subtruncate apex, with straight or very faintly sinuous lateral margins, and a slight apical notch with a tuft of setæ. Endopod of uropod scarcely twice as long as basal width; exopod narrower than usual, outer margin strongly emarginate distally, apex subacute or narrowly rounded.

7 mm.

Singapore (Copenhagen Museum).

*LEPTANTHURA THORI*, n. sp.

Resembles *L. tenuis*, but has the telson widest at base, narrowing very slightly to the rounded apex which bears a tuft of setæ not set in a notch; endopod of uropod more pointed.

7 mm.

N. Atlantic ('Thor' station no. 166. 62° 57' N., 19° 58' W.), 957 metres (Copenhagen Museum).

*LEPTANTHURA LÆVIGATA* (Stimpson) 1855.

(Syn. *L. faurei* Barnard, 1914. See also Vanhöffen, 1914.)

Telson widening distally to a broadly rounded apex with a tuft of setæ in a small notch. Exopod of uropod with deep apical incision, endopod not twice as long as broad. Four pairs of oostegites.

26 mm.

S. Africa, 25-87 fathoms.

*LEPTANTHURA TRUNCATA* Rich. 1911.

Peræon segments 5-7 each with two ventral processes on anterior part and two on posterior part of segment. Telson widening distally to a broadly rounded apex, but without notch. Exopod of uropod broadly ovate, not excised; endopod not twice as long as broad.

18 mm.

W. Africa, 888 metres.

I have seen the type specimens in the Paris Museum. The ventral processes seem confined to the adult or semiadult male.

*LEPTANTHURA CHILTONI* (Bedd.) 1886.

The type specimen, mounted on a slide in the British Museum, is undoubtedly referable to this genus. The telson is broadly rounded apically, without a notch, and resembles most nearly that of *L. truncata*. It may be the same as Haswell's *L. diemenensis*. Further specimens, however, are required to elucidate its true position.

N. of New Zealand, 700 fathoms.

*LEPTANTHURA DIEMENENSIS* (Hasw.) 1884.

(Original spelling *diemenensis*.)

This species seems clearly to be a *Leptanthura*, but more specimens are required before it can be diagnosed.

Tasmania, littoral.

Haswell's Australian species *Paranthura australis*, 1881, and *crassicornis*, 1881, are probably referable to this genus judging by the figures of the posterior peræopods.

Vanhöffen's *L. melanomma*, 1914, is a synonym of *Paranthura costana*.

## Gen. CALATHURA Norm. &amp; Stebb. 1886.

Eyes absent, or feebly pigmented specks fading in preservatives. Peræon not strongly keeled dorso-laterally, with dorsal pits; segment 7 short. Pleon not elongate, sutures distinct. Telson concave dorsally, thin, not indurated, without statocyst. Flagella of both antennæ with about 8-12 joints in both sexes, not brush-like in ♂. Mandible with 2nd joint not much longer than either of others, 3rd subequal to 1st, with comb of setæ. Maxilliped 5-jointed, 3rd joint very short, 2nd apically produced. Peræopod 1 with palm entire with basal tooth, unguis short. Peræopods 4-7 with 5th joint triangular, underriding 6th. Pleopod 1 not indurated. Uropods with exopod broad, folding over telson. Oostegites 3 pairs.

This genus as now defined contains only the single original species. For the other species see the genera *Accalathura* and *Leptanthura*.

## CALATHURA BRACHIATA (Stimpson) 1853.

(Syn. *C. norvegica* Sars, 1872. See also Richardson, 1905.)

Telson ovate-lanceolate, widest in the middle, apex acute, strongly concave dorsally in a longitudinal section, but plane in transverse section, a short narrow keel at base bearing a very fine median groove, followed by a very shallow ovate depression. (Pl. 4. fig. 19.) Other characters need not be specified.

45.5 mm.

N. Atlantic and Arctic Oceans, 5-735 fathoms.

## Gen. PARANTHURA Bate &amp; Westw. 1868.

(Syn. *Calamura* Boone, 1920.)

Eyes well developed. Peræon not strongly keeled dorso-laterally, no dorsal pits, but usually a fine impressed line across anterior margin of posterior segments; segment 7 short. Pleon short, sutures more or less distinct, more distinct laterally than dorsally. Telson flat or convex dorsally, sometimes concave dorsally, more or less convex ventrally, thin, not indurated, without statocyst. Antenna 1 with brush-like flagellum in ♂, 4-6-jointed in ♀. Antenna 2 with flagellum in both sexes composed of a single flattened joint which is very characteristic. Mandible with comb of setæ on 3rd palpal joint. Maxilliped 3-jointed, 2nd and 3rd joints subequal, 2nd joint not apically produced. Peræopod 1 with palm entire with more or less prominent basal tooth, unguis short. Peræopods 4-7 with 5th joint cylindrical, not underriding 6th. Pleopod 1 not indurated. Uropods with narrow or moderately broad exopods folding over telson. Oostegites 3-4 pairs.

This genus comprises species which are yellowish or pale, more or less suffused with darker speckling or patches, which however never form a clearly outlined pattern. They are mostly inhabitants of shallow water.



**PARANTHURA NIGROPUNCTATA (Lucas) 1849.**

(Non Norman &amp; Stebbing, 1886.)

Telson narrow, elongate, ovate-lanceolate, margins evenly convex and tapering to the acute setiferous apex, dorsally slightly convex. Endopod of uropod proportionately narrow, twice as long as broad, inner margin straight; exopod narrow-lanceolate,  $3\frac{1}{2}$ –4 times as long as broad, outer margin not sinuate, apex acute. (Pl. 4. fig. 21.) Four pairs of oostegites.

Pigment specks irregularly arranged. 15 mm.

N. Africa (Lucas); Mediterranean, 0–55 metres (Copenhagen Museum); Cape Verdes, 21–84 metres ('Talisman' coll. Paris Museum).

**PARANTHURA COSTANA Bate. & Westw. 1868.**

(= *P. nigropunctata* Norm. & Stebb. 1886, non Lucas. Also syn. *L. melanomma* Vanh. 1914.)

Telson ovate-lanceolate, very similar to that of true *P. nigropunctata*, but apex less pointed. Endopod of uropod not twice as long as broad, inner margin straight; exopod ovate, much broader than in *P. nigropunctata*, not more than twice as long as broad, outer margin distally sinuate, apex subacute (see figure in Gerstücker, 1881, pl. 14. fig. 26). (Pl. 4. fig. 20.) Four pairs of oostegites.

Pigment specks not regularly arranged. 13 mm.

Mediterranean (Costa, Dohrn, Copenhagen Museum): El Araish, Morocco, 10–20 fathoms (Copenhagen Museum); Orotava, Canary Is. (British Museum); Cape Bojador, 355 metres ('Talisman' coll. Paris Museum. Identified by Miss Richardson as *P. nigropunctata*); English Channel (Bate and Westwood); Cape Verde Islands (Vanhöffen).

This species is most certainly distinct from the preceding and is, I believe, Bate and Westwood's *P. costana*, which Norman and Stebbing have misnamed and wrongly united with Lucas's *P. nigropunctata*.

Neither species has been adequately figured. Lucas shows a narrow pointed telson for his species; Bate and Westwood draw the telson of *P. costana* broader and more rounded apically. Norman and Stebbing, who compared Mediterranean and Channel Island forms, figure the *P. costana* form of telson, and evidently thought that no reliance was to be placed on Lucas's somewhat crudely drawn drawing. But the actual occurrence of the two forms proves that both drawings are correct but applicable to two different species.

As regards the exopod of the uropod all the figures suffer from the same defect, except that given by Gerstücker: the appendage is figured *in situ* on the animal and consequently foreshortened. Norman and Stebbing describe the exopod as "narrow, lanceolate," but their figure, even in the foreshortened position, shows it much broader than it is in true *P. nigropunctata*. Dohrn states very clearly that this appendage is "broad and shortly oval." Stephensen, 1915, assigns a specimen to *P. nigropunctata*, but remarks that the telson and uropods are somewhat narrower than in Dohrn's figure.

The confusion seems to have been brought about through the accident of Heller happening to send specimens of *P. costana* to Norman and Stebbing, who quite naturally presumed that in a comparatively small area such as the Mediterranean only one species would be living. It is still more curious that Dohrn apparently only found the one form (*costana*) at Messina, whereas I have seen specimens of both from this locality.

In fact, the almost complete coincidence of the areas of distribution of both forms might lead one to suspect a case of sexual dimorphism. This, however, can be ruled out of account because I have seen males, females, and young of both forms, all showing quite constantly the differential characters given above.

Vanhöffen's species seems clearly to be the same as this species, although I have not seen his specimens.

**PARANTHURA PUNCTATA (Stimpson) 1855.**

(Syn. *P. nigropunctata* Chilton, 1906, non Lucas; *P. costana* Thomson, 1882, non Bate & Westwood. See also Barnard, 1914.)

Telson ovate-lanceolate, margins sinuous near base, apex narrowly rounded, setiferous. Endopod of uropod longer than broad, but not twice as long as broad, inner margin straight; exopod broadly ovate, outer margin distally sinuous, apex subacute. Four pairs of oostegites.

Pigment specks irregularly arranged, or sometimes aggregated into spots, especially on tail-fan, usually numerous so that whole animal has a greyish appearance. 16 mm.

S. Africa, 0-80 fathoms (Stimpson, Barnard); New Zealand (Chilton); Port Adelaide and Gulf of St. Vincent (Adelaide Museum); Tasmania (Adelaide Museum); New South Wales (sent by Haswell to Chilton and seen by me).

In New Zealand this species appears to inhabit some of the freshwater lakes, as well as being found off the coast (Chilton, 1906).

This species is very close to *costana*, but may be distinguished by the sinuous margins of the telson near the base: in *P. costana* the margins diverge evenly right from the base.

**PARANTHURA LIFUENSIS Stebb. 1900.**

Apparently well characterised by the endopod of the uropod, which is shorter than broad, almost semicircular. Exopod broadly oval, apex bluntly pointed. Telson ovate, apex narrowly rounded, setose. Three pairs of oostegites.

8 mm.

Loyalty Islands (Stebbing); China Sea, 40-80 fathoms (Copenhagen Museum).

Though I have not seen the type I believe I am right in assigning the Copenhagen specimens to this species, with which they agree in respect of the telson and endopod of uropod. Stebbing's description of the exopod as

"proximally broad, narrow apex reaching . . ." is true of his enlarged figure of the pleon and telson at the bottom of the plate where this appendage is seen edgewise, but not of the smaller figure at the top of the plate where it is seen facing the observer broadside on. The China Sea specimens agree with the latter figure.

Both the Chinese specimens are ovigerous females with three pairs of oostegites.

*PARANTHURA FLAGELLATA* (Chilton) 1882 *a.*

(Syn. *P. ciliata* Whitel. 1901.)

Telson narrow-elongate, of nearly the same width throughout, apex subtruncate, finely crenulate, setose, postero-lateral angles rounded, dorsal surface flat, ventral convex. Endopod of uropod about as broad as long, ovoid, inner margin convex, outer margin merging into distal; exopod narrow-elongate, ovate, apex subacute, outer margin crenulate.

10 mm.

New Zealand (Chilton); New South Wales, 54-59 fathoms (Whitelegge).

I have seen male cotypes from Chilton, but none of Whitelegge's specimens. Nevertheless, I feel sure that *P. ciliata* is synonymous from the shape of the telson, though the exopod of the uropod is rather broader than in *P. flagellata*. Possibly Whitelegge's specimens were females, and there may be a slight sexual difference in this appendage.

*PARANTHURA INFUNDIBULATA* Rich. 1902.

(Syn. *P. verrilli* Rich. 1902 = ♀.)

Pleon very short. Telson elongate, narrow, nearly parallel-sided, the margins curving upwards posteriorly, more so in adult ♂ than in ♀ and immature specimens, apex truncate, crenulate in ♂, entire in ♀, ventral surface convex. Endopod of uropod rectangular, crenulate, dorsally concave; exopod narrow, elongate, subrectangular, crenulate.

Pigment specks chiefly on anterior or posterior margins, or both, of segments, and on pleon and tail-fan.

Bermudas (Richardson); St. Thomas, W. Indies (Copenhagen Museum).

The Copenhagen Museum specimen is an immature ♂, length 7 mm., with telson like that of *P. verrilli*.

*PARANTHURA PORTERI* (Boone), 1920.

Telson not extending beyond apex of peduncle of uropod, ovate, apex broadly rounded, dorsal surface flat, covered with long setæ, ventral surface convex, shorter in ♀ than ♂. Endopod of uropod only very little longer than broad, subrectangular; exopod broad, subrectangular, distal margin sinuous. Long setæ on dorsal surface of peduncle and endopod of uropod, and on inner surface of exopod facing telson.

10 mm.

Chile.

I have seen the ♂ and ♀ type specimens; they are both typical *Paranthura*.

**PARANTHURA NEGLECTA** Bedd. 1886.

Telson ovate, margins straight, nearly parallel or perhaps diverging very slightly distally, apex broadly rounded. Endopod of uropod ovoid, longer than broad, apex bluntly rounded; exopod broadly ovate, or slightly obovate, apex subtruncatæ, emarginate.

Kerguelen, 127 fathoms.

The breadth of the exopod of the uropod at once distinguishes this species, as also does the broad telson.

The description is drawn up from drawings of the type kindly made for me by Dr. Calman, who has remounted the type in the British Museum. When I was in England the type was mounted sideways on a slide as it was when originally examined by Beddard, and I was only able to convince myself that it belonged to this genus from the character of the maxilliped, flagellum of second antennæ, and the peræopods.

For other species of this genus see :

*P. australis* Hasw. and *P. crassicornis* Hasw. under *Leptanthura*.

*P. miersi* Hasw. under *Mesanthura*.

*P. japonica* Rich. 1910. This species is quite inadequately described and figured for comparison with other species.

The following two species agree with *Paranthura* in all respects except that the eyes are reduced to mere pigment specks or absent altogether, and the flagella of both antennæ in both sexes are reduced to single joints (5 very minute joints in antenna 1 of *P. involuta*); that of the 2nd antenna has not the compressed shape characteristic of a true *Paranthura*. For the present I am unwilling to institute a new genus for them.

**PARANTHURA (?) INVOLUTA** Whitel. 1901.

Telson ovate-lanceolate, margins near base sinuate, apex narrowly rounded. Endopod of uropod subtriangular, longer than broad, inner margin straight; exopod ovate with pointed apex.

New South Wales, 50–52 fathoms (Whitelegge).

With the exception of the eyes this species bears very considerable resemblance to *P. punctata*.

**PARANTHURA (?) ANTILLENISIS**, n. sp.

Telson ovate, lateral margins sinuous basally, apex narrowly rounded, setose, very similar to that of *P. involuta*, slightly convex dorsally. Endopod of uropod as long as broad, subcircular; exopod broadly ovate, apically rounded, outer margin crenulate. Three pairs of oostegites.

5.5 mm.

St. John and St. James, W. Indies, 16 fathoms (Copenhagen Museum).

Gen. CRUREGENS Chilton, 1882 *b*.

Eyes absent. Peræon not strongly keeled dorso-laterally, no dorsal pits; segment 7 very short and devoid of peræopods. Pleon short, sutures distinct. Telson thin, dorsally convex, not indurated, without statocyst. Flagella of both antennæ rudimentary. Mandible without palp. Maxilliped 2-jointed. Peræopod 1 with basal tooth on palm, unguis short. Peræopods 4-6 with 5th joint cylindrical, not underriding 6th. Pleopod 1 not indurated, inner ramus very narrow. Uropod with narrow, elongate exopod not arching over telson. Oostegites?

This remarkable genus is at once distinguished by the absence of the mandibular palp and the reduction of the maxilliped to a single (free) piece; as also by its habitat, which is unique in the family, although *Cyathura carinata* and *Paranthura punctata* are known to inhabit fresh as well as salt water.

CRUREGENS FONTANUS Chilton, 1882 *b*.

(See also Chilton, 1894.)

12 mm.

New Zealand, in freshwater wells.

## Gen. PSEUDANTHURA Rich. 1911.

Eyes absent. Anterior margin of head with a raised rim surrounding the bases of 1st antennæ, which are thus set in unusually deep sockets, and continued into the prominent rostrum. Peræon scarcely keeled dorso-laterally, without dorsal pits. Pleon not elongate, sutures distinct. Telson short and broad, thin, not indurated, convex dorsally, without statocyst. Antenna 1 with brush-like flagellum in ♂ (but see p. 111 *supra*), pauciarticulate in ♀. Antenna 2 with multiarticulate flagellum in both sexes. Mandible with comb of setæ on 3rd palpal joint. Maxilliped 3-jointed, 2nd joint with short acute projection on inner apex. Peræopod 1 with palm entire, without basal process, unguis short. Peræopods 4-7 with 5th joint cylindrical, not underriding 6th; peræopod 7 conspicuously shorter than the others. Pleopod 1 with outer ramus hardened, inner ramus very much smaller. Uropods without visible suture between peduncle and endopod, exopod reduced to a small movable scale. Oostegites 4 pairs, the 1st pair very small.

## PSEUDANTHURA LATERALIS Rich. 1911.

(See also Barnard, 1920.)

I have examined the types in the Paris Museum and find no difference between them and the Cape specimens.

22.5 mm.

W. Africa, 930-3200 metres (Richardson); S. Africa, 900-1000 fathoms (Barnard).

## INCERTÆ SEDIS.

Gen. COLANTHURA Rich. 1902.

Eyes well developed. Peræon segment 7 very short and narrower than the other segments and the pleon, without appendages. Pleon short, sutures distinct. Telson? Flagella of both antennæ rudimentary in ♀. Uropod with exopod arching over telson. Mouth-parts and oostegites? Male unknown.

Further characters of this form cannot be given; the original description is inadequate and I have seen no specimens.

COLANTHURA TENUIS Rich. 1902.

Bermuda.

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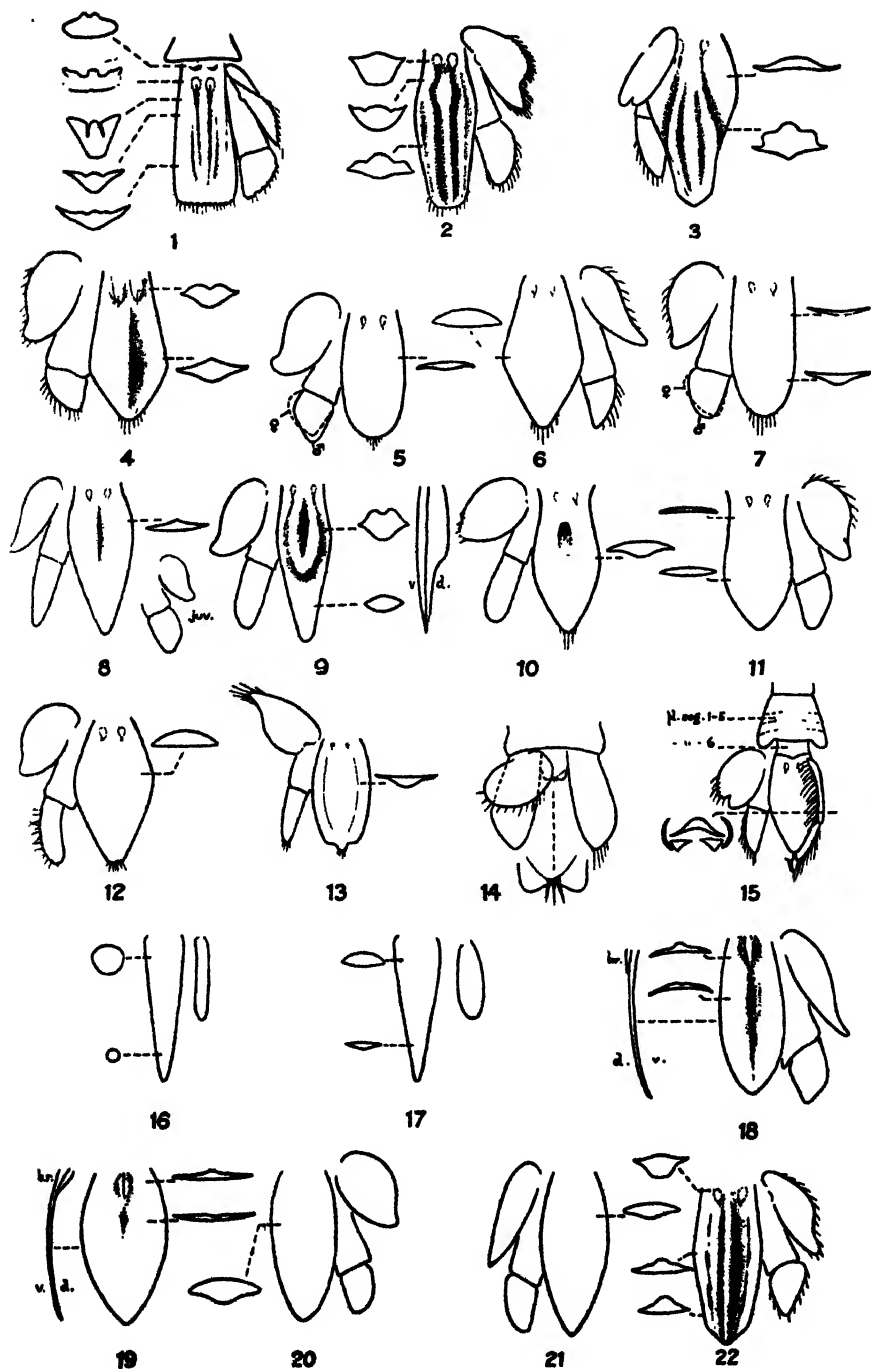
## EXPLANATION OF PLATE 4.

Semidiagrammatic figures representing the telsons and uropods of Anthurids in dorsal view and as seen in transverse section. Except in fig. 1 the exopod of the uropod is drawn as when laid flat facing the observer. The scale is not the same for all figures.

- Fig. 1. *Anthura gracilis* (Mont.).
2. *Haliophasma tricarinata*, n. sp.
  3. „ *purpurea* Hasw. Cotype in Brit. Mus.
  4. „ *dukarensis*, n. sp.
  5. *Cyathura crucis*, n. sp.
  6. „ *siamensis*, n. sp.
  7. „ *indica*, n. sp.
  8. *Anthelura elongata* Norm. & Stebb. Types in Brit. Mus.
  9. *Ananthura sulcatacauda*, n. g. et sp.
  10. „ *ovalis*, n. sp.
  11. *Apanthura senegalensis*, n. sp.
  12. „ *coppingeri*, n. sp.
  13. *Kupellonura mediterranea*, n. g. et sp.
  14. *Xenanthura brevitetson*, n. g. et sp.
  15. *Skuphonura laticeps*, n. g. et sp.
  16. *Hyssura producta* Norm. & Stebb. Type in Brit. Mus.
  17. „ *profunda*, n. sp.
  18. *Accalathura crenulata* (Rich.). Paris Museum specimen.
  19. *Culathura brachiata* (Stimpson).
  20. *Paranthura costana* Bate & Westw.
  21. „ *nigropunctata* (Lucas).
  22. *Exanthura filiformis* (Lucas). A South African specimen.

In figs. 9, 18, and 19 the letters "d" and "v" indicate the dorsal and ventral surfaces of the telson seen in lateral view.





ANTHURIDÆ.



Some Tetrabothriid Cestodes from Whales of the Genus *Balenoptera*. By  
H. A. BAYLIS, M.A., D.Sc. (Communicated by Dr. W. T. CALMAN,  
F.R.S., Sec.L.S.)

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(With 6 Text-figures.)

[Read 20th November, 1921.]

THE Cestodes parasitic in Cetacea are not yet very well known, only some seven species having been recorded as adults and two in the cysticercus stage. In the following contribution to the subject no new species are described, but an attempt is made to clear up certain points in the anatomy, classification, and nomenclature of some of the known species.

Parasites of whales possess a certain interest from the point of view of the mammalogist as well as that of the helminthologist, for the study of parasitic forms from the Northern and Southern hemispheres may throw some light upon the distribution and migrations of the hosts, and the identity or otherwise of the Northern and Southern whales of the same genus. One of the Cestodes dealt with in this paper apparently occurs in species of *Balenoptera* in both hemispheres. A Nematode—*Crassicaula crassicaula* (Crepl.)—that inhabits the urino-genital organs of *Balenoptera*, seems likewise to occur in both Arctic and Antarctic seas. Nothing is known of the life-history of either of these worms, so that we are hardly in a position as yet to estimate the importance of their distribution.

PRIAPOCEPHALUS GRANDIS Nybelin, 1922. (Fig. 1, p. 162.)

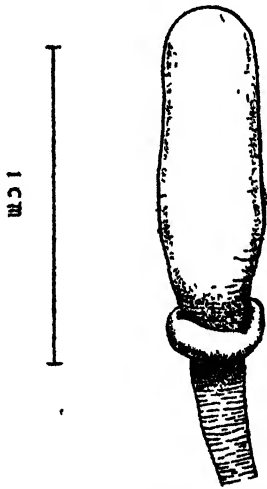
Dr. E. A. Chapin (1921) read before the Helminthological Society of Washington some notes on a remarkable and hitherto unknown Cestode from the Blue Whale (*Balenoptera musculus*), having a scolex of peculiar cylindrical shape, which could be buried in the host's mucous membrane and then become spherical, thus, as it were, "riveting" the parasite to its host. The material had been collected by Mr. A. F. Bearpark at Cape Point, South Africa, and was presented by him to the United States National Museum. The species was not fully described or named by Chapin.

About two years later the British Museum (Natural History) received from H.E. the Governor of the Falkland Islands some whale-parasites obtained by Mr. A. G. Bennett at Deception Island, South Shetlands. These included specimens of a Cestode from *Balenoptera musculus*, answering to the brief description given by Chapin. The writer communicated with

Dr. Chapin, and, through his kindness and that of Dr. B. H. Ransom, obtained the loan of a part of the material from South Africa for comparison. In the meantime, however, Nybelin (1922) had described, under the name of *Priapocephalus grandis*, n. g., n. sp., what is undoubtedly the same worm from *Balaenoptera borealis* and *B. intermedia*\*, collected at South Georgia. A comparison of preparations and sections of the two sets of specimens available with Nybelin's descriptions and figures gives no reason to doubt the specific identity of all the material.

The genus *Priapocephalus*, as is shown by the anatomy of the mature segments, undoubtedly belongs, as Nybelin considers, to the family Tetrabothriidae. Its chief peculiarity is the scolex, which consists of a bulb-like

FIG. 1.



*Priapocephalus grandis*.  
Scolex of specimen from *Balaenoptera musculus*.  
(U.S. Nat. Mus., Cat. No. 7597.)

anterior portion, capable of assuming various shapes and very variable in size according to state of contraction, and a posterior collar-like thickening. There are no suckers of any kind. In the material collected by Mr. Bennett the entire scolices (including the "collar") were buried deeply in the mucous membrane of the intestinal wall, and were preserved in this condition. With great care it was found possible to extract them undamaged. These scolices were much smaller than that of the specimen lent by the U.S. National Museum, the anterior portion of which is also larger and more cylindrical in shape than those described by Nybelin. A figure of this very fine specimen is given (fig. 1).

\* *B. intermedia* is probably identical with *B. musculus*.

The genus *Priapoccephalus* shows a new modification of the Tetrabothriid scolex. The writer (1922) has already described a form (*Anophryocephalus anophrys*) in which the characteristic "auricular appendages" are absent, but four suckers are still present. In *Priapoccephalus* even the suckers have disappeared, and the scolex has taken on an entirely new aspect, resembling somewhat that of certain Tetraphyllidea, such as *Discocephalum* and *Tylocephalum*, in which there is an anterior, fleshy "myzorhynchus" and a posterior swelling, with or without suckers.

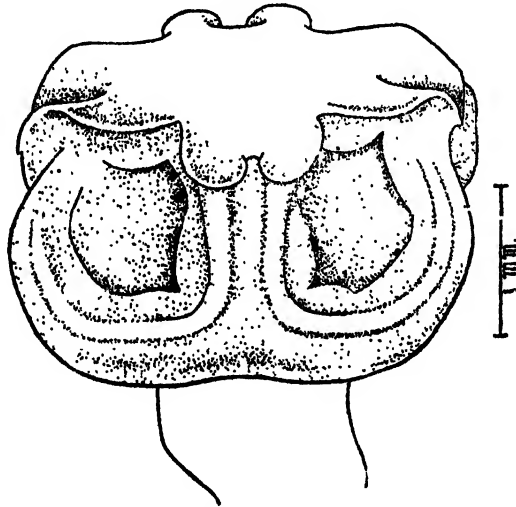
*TETRABOTHRIUS AFFINIS* (Lönnerberg, in Jägerskiöld, 1891). (Figs. 2-5.)

Syn. *Diplobothrium affine* Lönnerberg, in Jägerskiöld (1891).

*Tetrabothrium* (*Diplobothrium*) *affine* Lönnerberg (1892).

The material upon which the following notes are based consists of—  
(1) numerous large specimens in good, though much contracted, condition

FIG. 2.



*Tetrabothrius affinis*.

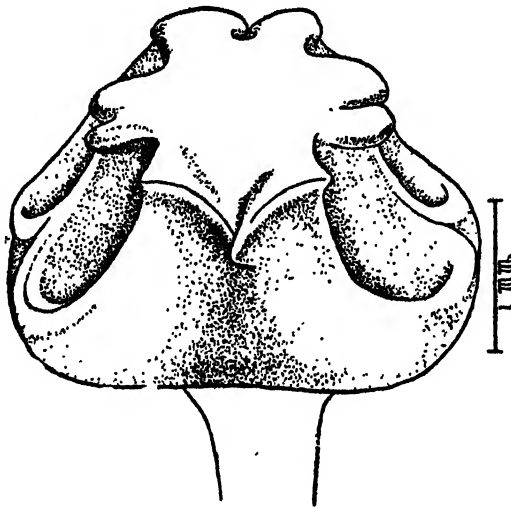
Scolex in relaxed condition; dorsal or ventral view.

taken by Mr. A. G. Bennett from the intestine of *Balenoptera musculus* at the South Shetlands; (2) several specimens collected at Capetown, South Africa, from the small intestine of *B. borealis*, and presented to the British Museum in 1920 by Mr. A. F. Bearpark. These specimens are in an extended condition, but not as well-grown as the former. (3) A few much-contracted specimens, of moderate size, kindly lent for comparison by the United States National Museum, through the courtesy of Drs. B. H. Ransom and E. A. Chapin. This material is part of a series from *Balenoptera musculus*, off Cape Point, South Africa, also collected by Mr. A. F. Bearpark

(4) No-type material of *Diplobothrium affine* Lönnerberg, from *Balnoptera borealis*, taken off Finmark, Norway. These specimens are the property of the Zoological Institution of the University of Upsala, and were lent to the writer for comparison through the kindness of Prof. Einar Lönnerberg, of Stockholm, and Dr. I. Arwidsson, of Upsala.

As a result of careful comparison and drawing to scale of scolices from all the sets of material, and the study of serial sections, both horizontal and transverse, of the strobilæ, the conclusion has been reached that, in spite of great differences in external appearance, all the specimens belong to the same species, viz. that originally described by Lönnerberg. The amount of

FIG. 3.

*Tetrabothrius affinis.*

Lateral view of the relaxed scolex represented in fig. 2.

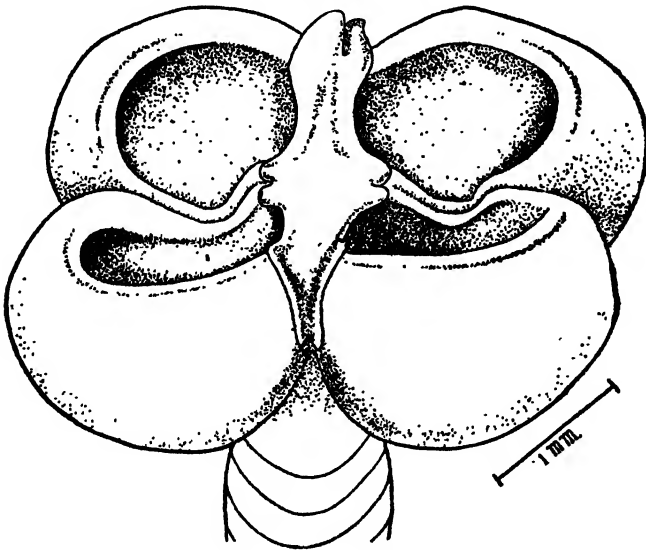
variation possible in the shape of the scolex, according to its state of contraction, is surprisingly great\*, as figs. 2-4 show, but anatomically there are no valid distinctions between one series of specimens and another. For reasons which will be fully explained, the species is referred to the genus *Tetrabothrius*.

As Lönnerberg's (1892) description, though very detailed as regards the histology of the scolex and strobila, and the excretory, nervous, and muscular systems, was necessarily incomplete owing to the immaturity of his material, some further account of the anatomy is given here.

\* Cf. Fuhrmann's (1899, pp. 864-866) remarks on the variability of form of the scolex in *Prostheocotyle*.

The length of entire specimens varies from 45 to 200 mm., according to maturity and degree of contraction. The maximum width of the strobila is 3–5 mm., and its dorso-ventral thickness 0·85–2·5 mm., these measurements, of course, also varying greatly with age and state of contraction. The scolex has a maximum diameter, measured across the suckers, of 3–4 mm. both dorso-ventrally and laterally, and its dimensions do not vary greatly in different states of contraction, although its shape is so variable. The suckers, which have an outside diameter of about 1·3–1·5 mm., are arranged in two pairs, dorsal and ventral. In extended specimens they are widely

FIG. 4.

*Tetrabothis affinis.*

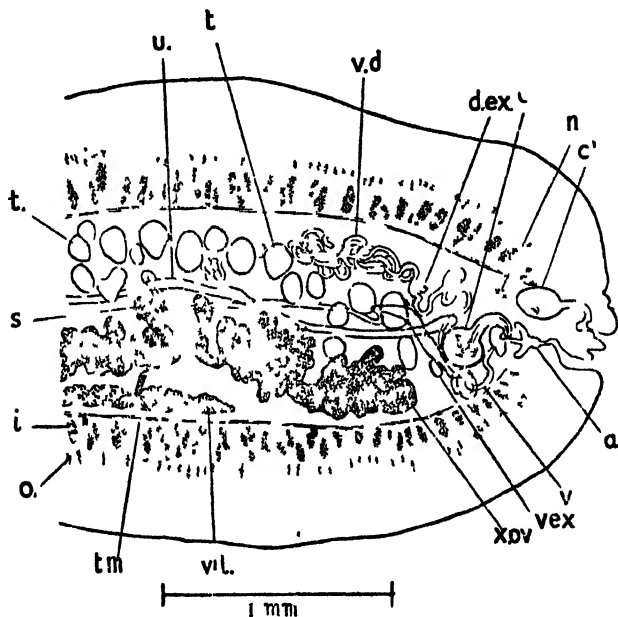
Scolex in contracted condition; lateral view.

open and hang down from the anterior portion of the scolex in a manner very typical of *Tetrabothis*. When contracted, however, their posterior edges are drawn up, and the whole sucker is brought forward so that its opening faces anteriorly.

The central or anterior portion of the scolex is occupied by very characteristic muscular structures clearly homologous with the "auricular appendages" of other species of *Tetrabothis*. At the summit there is a flattened or sometimes slightly concave area, elongated in the transverse direction. In front of the septa dividing the pairs of suckers dorsally and ventrally, this runs out into two pairs of small, rounded "epaulettes." Laterally it is produced into two pairs of curved, somewhat flattened processes, the edges of which overhang the suckers, and whose shape is best indicated by means

of the accompanying figures. When the scolex is relaxed and the suckers in the pendent position, the apical area is relatively wide and the "epaulettes" large and conspicuous. In the contracted condition, however, the width of the apical area is enormously reduced, and the "epaulettes" become very small. The transverse diameter of the apical area does not vary to any great extent in the two conditions. The apical area and its appendages are not shown in Lönnerberg's (1892) figures, but are present in the type-material as in other specimens.

FIG. 5

*Tetrabothrius affinis*

Right half of a transverse section through a mature segment (semi-diagrammatic reconstruction from several consecutive sections).

*a.*, genital atrium, *c.*, cirrus-sac, *c'*, cirrus-sac belonging to another segment, cut through in same section, *dex.*, dorsal excretory canal, *i*, inner layer of longitudinal muscles, *n*, nerve, *o.*, ovary, *ov*, ovary; *s*, shell-gland, *t.*, testes, *tm*, transverse muscles, *u.*, uterus; *v*, vagina; *v.d.*, vas deferens, *v.ex.*, ventral excretory canal; *mt*, yolk-gland.

The number of segments is almost impossible to estimate in mature specimens, owing to extreme contraction. Segments 3.7 mm. in width may have a length of only 0.1 mm., as shown by horizontal sections. Throughout the strobila the segments are very much broader than long, and only in the most posterior is there any tendency to become elongated and proportionately narrower.



The subcuticular layer is well supplied with the usual muscle-fibres, especially those running longitudinally, and with deeply-staining cells. The cortical parenchyme, in contracted specimens, accounts for at least half of the dorso-ventral diameter of the segments. The transverse muscle-layer separating the cortical from the medullary parenchyme is not greatly developed. The longitudinal musculature, however, is very powerful, consisting of an inner layer of large bundles (about 70 to 130 bundles dorsally and a similar number ventrally), each containing up to 100 fibres or more, and an outer layer of small bundles, each containing on an average about ten fibres.

The usual narrow dorsal and wider ventral longitudinal pairs of excretory canals are present, and the latter are connected by transverse intersegmental vessels. The genital pores, as usual, are all on the right side, each leading into a deep genital atrium. In contracted specimens adjacent pores tend to alternate with each other at different levels, so that the genital atria and cirrus-sacs of two successive segments may be cut through in a single transverse section. Both genital ducts pass between the two longitudinal excretory vessels and ventrally to the nerve of the right side. The cirrus-sac is more or less spherical, measuring 0.2–0.25 mm. in diameter and opening through a curved "male cloacal canal" into the dorsal side of an inner chamber of the atrium. Towards the ventral side of this chamber is the narrow opening of the vagina. This duct, which is lined with setæ, passes below the cirrus-sac and then turns dorsally, at the same time expanding considerably. It then turns and runs as a narrower tube again almost straight towards the middle of the segment, to its connection with the shell-gland and other female organs.

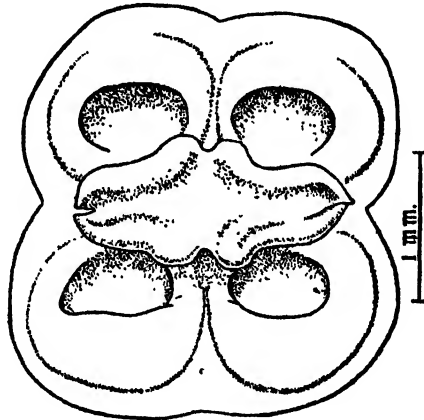
The vas deferens is greatly coiled, occupying a considerable portion of the right dorsal sector of the segment. The testes are arranged in a single layer occupying the whole of the back of the segment between the dorsal and ventral transverse muscles. They also extend forward dorsally to the female organs. The average diameter of the testes in mature segments is about 0.16 mm. It has not been found possible to count them, and their number is very difficult to estimate with any accuracy. On a very rough calculation there must be at least 100 testes in each segment, and the number is very probably greater than this.

The transversely elongated ovary extends across the anterior half of the segment, towards the ventral side. It is much lobulated, especially on the dorsal side, and is more or less distinctly divided into two lateral portions. Immediately ventrally to the ovary, and at the extreme anterior limit of the medullary parenchyme, lies the smaller yolk-gland, which is also transversely elongated. The uterus appears early as a transverse tube running across the segment just dorsally to the ovary. Later it expands into an irregular sac with many outpocketings, as is usual in *Tetraphothrius*. Fully-formed

onchospheres were not seen in the uterus in the specimens studied, the gravid segments being probably thrown off before the ova reach this stage of development.

Spätlich (1909), Fuhrmann (1921), and Nybelin (1922) have described in various species of *Tetrabothrius* a column of cells connecting the uterus with the dorsal subcuticular layer in each segment, and it has been suggested that this is the rudiment or vestige of a duct leading to the exterior, like the uterine pore of the Bothriocephalid group. Nybelin (*l.c.*) even states that he has detected a lumen in this structure in the older segments of *Tetrabothrius polyorchis*. In *T. affinis* there is a similar column of cells, consisting of a dense core of parenchymatous fibres, surrounded by numerous cells with distinct nuclei. No actual lumen, however, has been detected.

FIG. 6.

*Tetrabothrius wilsoni*.

Scolex in contracted condition; frontal view.

**TETRABOTHRUS WILSONI** (Leiper & Atkinson, 1914). (Fig. 6.)

Syn. *Oriana wilsoni* Leiper & Atkinson, 1914.

The genus *Oriana* was proposed by Leiper & Atkinson (1914) with the following diagnosis: "Cyclophyllid with large quadrate discoidal head carrying four round suckers. Rostellum absent." *O. wilsoni*, from *Balanoptera borealis*, captured off New Zealand, was designated as genotype, and briefly described as follows: "Segments all immature. Strobila 13 cms. Head discoidal, 3 mm. in diam., quadrate in outline, 4 round suckers present terminally. Neck very slender. Testes arranged in two definite groups of 7-8 and 17-18. Near to *Diplobothrium*."

This description was amplified later (1915), and the species was figured. The figures of the scolex (*l.c.*, pl. 5. figs. 32, 33) hardly indicate the real

nature of its structure, the four suckers being shown as disposed at the four corners of an almost square, perfectly plain surface. A re-examination of the co-type material in the British Museum (Natural History) shows that the scolex is of precisely the same type as that of *T. affinis*. The worms are all immature, and little can be said of the anatomy of the segments. While the question of the specific identity of *O. wilsoni* with *T. affinis* seems to the writer to be an open one, the smaller average size of the scolex in *wilsoni* may possibly be a good reason for considering the species distinct. The characters of the scolex, however, indicate clearly that *O. wilsoni*, like the other form, is a *Tetrabothrius*, and that the genus *Oriana* must fall into synonymy.

*PROSTHECOCOTYLE, DIPLOBOTHRIUM, ORIANA, AND TETRABOTHRIUS.*

Lönnerberg (1892) regarded *Diplobothrium* \* van Beneden, 1889, as a subgenus of *Tetrabothrium* (= *Tetrabothrius* Rud., 1819). Monticelli (1892) erected a genus *Prosthecocotyle* for *Tania forsteri* Kreff, 1871, a species from *Delphinus* which seems clearly to be congeneric with *Diplobothrium affine*. Fuhrmann (1899) adopted the genus *Prosthecocotyle*, placing in it not only *P. forsteri* and *P. triangulare* (Dies.) from Cetacea, but also all the species from birds that had previously been referred to *Tetrabothrius*. Fuhrmann and almost all other recent authors, however, have now adopted the view that *Prosthecocotyle* is a synonym of *Tetrabothrius*.

The question of the distinctness of *Prosthecocotyle* has been raised again very recently by Linton (1923), who considers it "hardly to be expected that closely related cestodes should be found in such widely dissimilar hosts as birds and cetaceans." In describing a new species, which is named *Prosthecocotyle monticellii* †, from *Globicephalus melas*, Linton says that a comparison of it with "... such typical avian cestodes as *Tetrabothrius macrocephalus* (Rud.) and *T. erostris* (Kreff) ... shows no such resemblance as a generic kinship demands. On the other hand its resemblance to *Prosthecocotyle forsteri* (Kreff) seems to be sufficient to justify referring it to the same genus. If this conclusion is correct, then the names used by Monticelli should stand. They are: *Prosthecocotyle forsteri* (Kreff) from *Delphinus delphis*, and *P. triangulare* (Dies.) from *Delphinorhynchus rostratus*."

The first statement quoted seems undoubtedly to be correct, but the rest of the argument depends entirely upon the generic relationship between Linton's species from *Globicephalus* and that from *Delphinus* described by Monticelli as *P. forsteri*, since Monticelli's species is the genotype of

\* The name *Diplobothrium* is preoccupied by *Diplobothrium* Leuckart, 1842 [Trematoda].

† This combination of names is preoccupied by *P. monticelli* Fuhrmann, 1899, from *Fulmarus glacialis*.

*Prosthecotyle*. A rough translation of Monticelli's diagnosis of the genus is as follows :—

“Body lanceolate anteriorly. Head small, swollen, quadrangular, distinct from neck, with four little tubercles at the four anterior angles. Suckers large, powerful, each furnished antero-laterally with an elongate appendage. Neck short, hardly distinct from body. Segments very close together, imbricated, much broader than long. Genital pores marginal, unilateral.”

To this may be added a rough translation of Monticelli's description of the scolex of *P. forsteri*. After remarking upon the great differences in shape observed in different states of contraction, he says :—

“[The head] is much flattened dorso-ventrally, wide anteriorly, narrow posteriorly . . . . Anteriorly, in the centre, it is swollen, . . . . and at the four angles there arise four little fleshy tubercles with rounded points. . . . Laterally and subdorsally from each sucker there originates, anteriorly, an appendage of characteristic shape, ending in a point turned towards [one of] the four anterior, prominent angles of the head, of which they [*sc.* the angles] are the support, which resemble the horn of an ox or the beak of a bird. These appendages are not independent of the suckers, but form with them a single body and are composed of muscular fibres that belong to the system of radial fibres of the suckers, of which they are a continuation. . . .”

Now this account of *Prosthecotyle*, and Monticelli's figures, contain nothing that is at variance with the characters of *Tetrabothrius*. They agree, on the whole, with the accounts and figures given in this paper of *Tetrabothrius affinis* and *T. wilsoni* \*. But, in the writer's opinion, they do not agree equally closely with Linton's account and figures of the species from *Globicephalus*. In this form each sucker shows three small, separate appendages, disposed at equal intervals round its edge, and the presence of a well-developed apical portion of the scolex like that described in the other forms is not indicated at all. There appear also to be some important differences in the anatomy of the segments (the anterior position of the testes, for example). The writer, therefore, concludes that :—

(1) *Prosthecotyle monticellii* Linton (*nec* Fuhrmann) is probably not congeneric with *P. forsteri* (Kreffft) of Monticelli.

(2) *Diplobothrium affine* and *Oriana wilsoni* belong to the same genus as the *P. forsteri* of Monticelli.

\* From Monticelli's figures it is evident that his “four little fleshy tubercles” are not what were termed the “epaulettes” in *T. affinis*, but are the lateral appendages. The “epaulettes” do not seem to have been observed by Monticelli. The “appendages” of the suckers, therefore, must mean those portions of the lateral appendages which are in continuity with the suckers. In other words, the “tubercles” and the “appendages” are both parts of the same structure.

(3) There is nothing in the characters of these three species, so far as they are known, to prevent their inclusion in the genus *Tetrabothrius* Rudolphi.

(4) The names *Prostheccocotyle* Monticelli, *Diplobothrium* v. Ben. of Lönnberg\* (*nec* Leuck.), and *Oriana* Leiper & Atkinson, are all synonyms of *Tetrabothrius* Rud.

NOTE ON THE SYSTEMATIC POSITION OF *TETRABOTHIUS* RUD., 1819.

*Tetrabothrius* has generally been regarded as belonging to the Cyclophyllidean group of Cestodes. Recently, however, Nybelin (1922) has treated the Tetrabothriidæ as belonging rather to the Pseudophyllideæ. He finds many resemblances in their anatomy to that of the Abothriinæ, a new subfamily proposed by him to include *Abothrium* van Beneden, *Bathybothrium* Lühe, and a new genus, *Parabothrium*.

If we concentrate our attention upon the characters of the scolex, which is usually regarded as of primary importance in Cestode classification, it seems clear that *Tetrabothrius* must be related either to the Cyclophyllideæ or to the Tetraphyllideæ. As compared with the former group, it is peculiar in the position of the yolk-gland with regard to the ovary and other organs in mature segments. Usually included in the Tetraphyllideæ is a genus which seems to the writer to be of great interest when compared with *Tetrabothrius*. This is *Dinobothrium* van Beneden, 1889, a recent study of which has been made by Linton (1922). In this genus, according to Linton, the yolk-glands, which consist of numerous separate follicles, are situated ventrally to the ovary (as in some species of *Tetrabothrius*, including those dealt with in this paper), and immediately above the longitudinal muscles, transverse muscles being apparently absent. *Dinobothrium*, therefore, is scarcely a typical Tetraphyllidean, since its yolk-glands are within the musculature and not in the cortical parenchyme. The general arrangement of the genital organs is similar in many respects to that found in *Tetrabothrius*, but it is in the scolex that the most obvious resemblances are seen.

In *Dinobothrium* there are four large bothria, arranged in dorsal and ventral pairs. When relaxed, these bothria are open, shallow and pendent, but their edges can be turned inwards and forwards to a considerable extent, very much after the fashion of the suckers of *Tetrabothrius affinis*. The bothria are continuous anteriorly with complex "auricular appendages" formed on the same general plan as those which have been described for *T. affinis*. They run out laterally into rather thin, curved flanges which are more or less conspicuously notched, and are also provided with little tubercles or ridges on either side of the mid-dorsal and mid-ventral lines, as in *T. affinis*.

\* Whether *Diplobothrium*, in the original sense of van Beneden, is entirely a synonym of *Tetrabothrius* depends upon the question whether its genotype, *D. simile*, from *Lamna cornubica*, is congeneric with *D. affine* and with the type of *Tetrabothrius*.

The chief point of difference is that in *Dinobothrium* there are four small semicircular "accessory suckers" on the summit of the scolex.

It seems altogether not too much to suggest that these two genera must be very closely related, and it is not impossible that through such forms as *Tetrabothrius* and *Dinobothrium* the groups Cyclophyllidea and Tetraphyllidea grade into each other, and are perhaps also connected with the Pseudophyllidea. *Dinobothrium* ought, perhaps, to be regarded as a member of the family Tetrabothriidae.

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On the Parasitic Mites of the Suborder Prostigmata (Trombidioidea) found on Lizards. By ARTHUR STANLEY HIRST, F.L.S.

[Submitted by permission of the Trustees of the British Museum.]

(With 19 Text-figures.)

[Read 19th March, 1925.]

THE following account deals with the parasitic mites of the super-family Trombidioidea living on lizards.

Some species of lizards harbour more than one form of *Geckobia*. For instance, two forms occur on *Tarentola mauritanica*, viz. *Geckobia latasti* and *G. loricata*, whilst Trägårdh records two forms as being found on *Tarentola annularis*. Two distinct forms live on *Hemidactylus brooki* (syn. *gleadori*) and three different forms on *H. leschenaulti*. When more than one form of *Geckobia* is found on the same host, one form usually lives beneath the ventral scales and is flattened, being considerably wider than long and having scales instead of hairs on the venter. The second form occurring on the same host is usually to be discovered between the claw and pad of the toes, between the laminae of the pad, or between the toes themselves; this form is normally practically spherical in shape and has hairs instead of scales on the venter. It is difficult to decide whether these different forms living on the same host are heteromorphic forms of a single species or separate species. In view of the rather considerable structural differences between them, it is wiser at present to regard these forms as distinct species. The question can only be settled by breeding a series of these mites and making careful observations on living specimens.

There is no record of any of these Trombidiid mites that live on lizards attacking human beings. The structure of the mouth-parts of these mites and also the remarkable resemblance of their larvæ to those larval Trombidiid forms known to attack warm-blooded animals suggests, however, the possibility of their attacking other hosts besides lizards. Some of the lizard hosts on which these mites are found (for instance, *Tarentola mauritanica*, *T. annularis*, *Hemidactylus turcicus*, etc.) are known to frequent human habitations, and have been suspected of acting as reservoirs for Kala-azar; hence a census of their parasites may perhaps be of interest.

*Key to the Genera of Prostigmata (Trombidioidea) living on Lizards.*

- |    |   |                                                                                       |                            |
|----|---|---------------------------------------------------------------------------------------|----------------------------|
| 1. | { | Hairs or scales on venter numerous. Stout setæ or spurs usually present on coxæ ..... | <i>Geckobia</i> Meguin.    |
|    |   | Hairs on venter few in number. No spurs on coxæ .....                                 | 2.                         |
| 2. | { | Body very much wider than long .....                                                  | <i>Pterygosoma</i> Peters. |
|    |   | Body longer than wide .....                                                           | 3.                         |

3. { Hairs on dorsum few in number. Scutum absent ..... *Hirstiella* Berlese.  
 { Hairs on dorsum numerous ..... 4.
4. { Hairs on dorsum numerous, very short, and somewhat enlarged distally. No scutum. Projecting part of peritremal tube long ..... *Geckobiella* Hirst.  
 { Hairs on dorsum very long, slender, not enlarged distally and not very numerous. Scutum present. Projecting portion of peritreme very short ..... *Pimeliaphilus* Trägårdh.

NOTE. The host of *Hirstiella* is not known, but probably is a lizard. One of the species of *Pimeliaphilus*, viz. *P. polapolipophagus* Trgdh., was found under the elytra of an Egyptian beetle; the other two species occur on lizards.

### Genus GECKOBIA Mégn.

#### *Key to the Species of the Genus Geckobia Mégnin (females only).*

1. { Dorsal hairs club-shaped, the distal ends being enlarged .... *G. clelandi* Hirst.  
 { Dorsal hairs not club-shaped ..... 2.
2. { Fourth legs much larger than the others ..... 3.  
 { Fourth legs not much longer than the others. .... 7.
3. { Spur on femur of fourth leg placed on a strong protuberance. *G. papuana* Hirst.  
 { Spur on femur of fourth leg not placed on a protuberance .. 4.
4. { Venter with scales ..... *G. australis* Hirst.  
 { Venter with setæ or hairs ..... 5.
5. { Body longer than wide. Third leg rather swollen ..... *G. boulengeri* Hirst.  
 { Body wider than long. Third leg not much stouter than anterior legs ..... 6.
6. { Some of the anterior setæ on the dorsum enlarged. Fourth leg not so stout ..... *G. malayana* Hirst.  
 { Anterior setæ not so stout. Fourth legs very stout ..... *G. gehyra*, sp. n.
7. { Venter with setæ or hairs ..... 8.  
 { Venter with scales ..... 12.
8. { Hairs on dorsum unequal in length; numerous quite short hairs in middle of dorsum ..... 9.  
 { Hairs on dorsum mostly fairly elongated; only a few short hairs anteriorly ..... 10.
9. { Body oval. Hair on first free segment of palp fine and plain. *G. diversipilis*, sp. n.  
 { Body rather wide. Hair on first free segment of palp slender but plumose ..... *G. indica* Hirst.
10. { Dorsal scutum obsolete. Only one pair of short anterior hairs on the dorsum ..... *G. latasti* Mégnin.  
 { Scutum better developed. 15-20 short anterior hairs on the dorsum ..... 11.



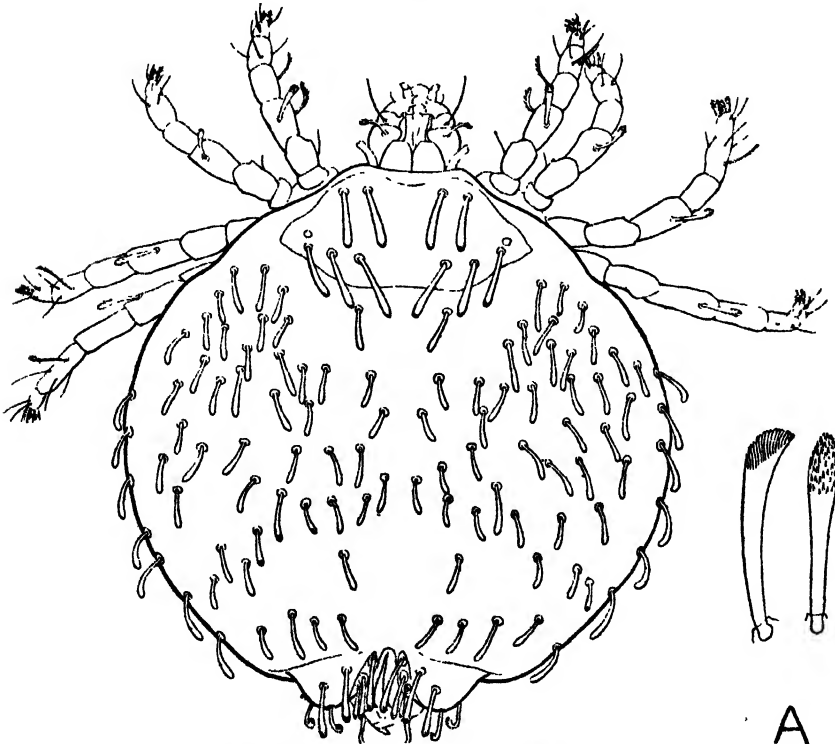
11. { Seta on first free segment of palp rather long and fine . . . . . *G. gleadowiana*, sp. n.  
       { Seta on first free segment of palp rather short and stout . . . . . *G. simplex*, sp. n.
12. { Scales in middle of venter shaped like the head of a spear . . . . . 13.  
       { Scales in the middle of venter fan-shaped or heart-shaped . . . . . 14.
13. { Scales rather long and slender . . . . . *G. hindustanica*, sp. n.  
       { Scales wider and not so elongate . . . . . *G. socotrensis* Hirst.
14. { Hairs in middle of venter fan-shaped . . . . . *G. tarantula* Trägårdh.  
       { Hairs in middle of venter short and wide (heart-shaped) . . . . . 15.
15. { Some rather stout but not long hairs anteriorly on the dorsum,  
       also numerous very short but stout hairs; posteriorly there  
       are more elongated hairs. Coxal spurs very strong . . . . . *G. loricata* Berleso.  
       { Anterior hairs scarcely stouter than the others; hairs on rest  
       of dorsum all slender and fairly elongated; very short hairs  
       are not present. Coxal spurs rather weak . . . . . *G. turkestanica*, sp. n.

*GECKOBIA CLELANDI* Hirst. (Fig. 1.)

Ann. & Mag. Nat. Hist. (8) xix. pp. 138 & 139 (1917).

♀. Body sac-shaped, being about as wide as long. Dorsal scutum well

FIG. 1.



*Geckobia clelandi* Hirst, ♀. Dorsal view.

A. Dorsal setae, enlarged.

developed, much wider than long and furnished with ten hairs similar to those on the rest of the dorsum, but slightly larger. All hairs on dorsum club-shaped, the distal ends being enlarged and plumose. Hairs on venter numerous and of the same type as those on the dorsum, but considerably smaller. Spurs on coxæ weak. Hair on dorsal surface of first free segment of palp slender, not very long and plumose distally.

*Length* of body .64 mm. ; its width .61 mm.

*Habitat.* Sydney and Narabeen, New South Wales (Dr. J. Burton Cleland's Coll.) ; on *Gymnodactylus platyrus*.

**GECKOBIA PAPUANA** Hirst. (Fig. 2.)

Ann. & Mag. Nat. Hist. (8) xix. p. 140 (1917).

♀. Body considerably wider than long. Scutum apparently reduced to two minute platelets as in *G. loricata* Berl. and *G. latasti* Mégn., each bearing two or three setæ and also the usual very minute eye. Between these two platelets there are two groups, each composed of four stout plumose setæ. Behind these there are numerous setæ of the same type, but very much smaller and very short. Posteriorly on and near the margin there are longer hairs which are indistinctly feathered. Hairs in the middle of the venter not very long and shaped rather like the head of a spear, being somewhat flattened and very sharply pointed ; posteriorly they become longer. Spurs on coxæ very strongly developed ; there is also a spur on the trochanter and femur of the fourth leg, that on the femur being placed on a large protuberance. Last pair of legs greatly swollen, the anterior legs slender. Hair on dorsal surface of first free segment of palp slender, plumose, and of moderate length.

*Length* of body .34 mm. ; its width .5 mm.

*Habitat.* German New Guinea ; under ventral scales of *Gymnodactylus louisianensis*.

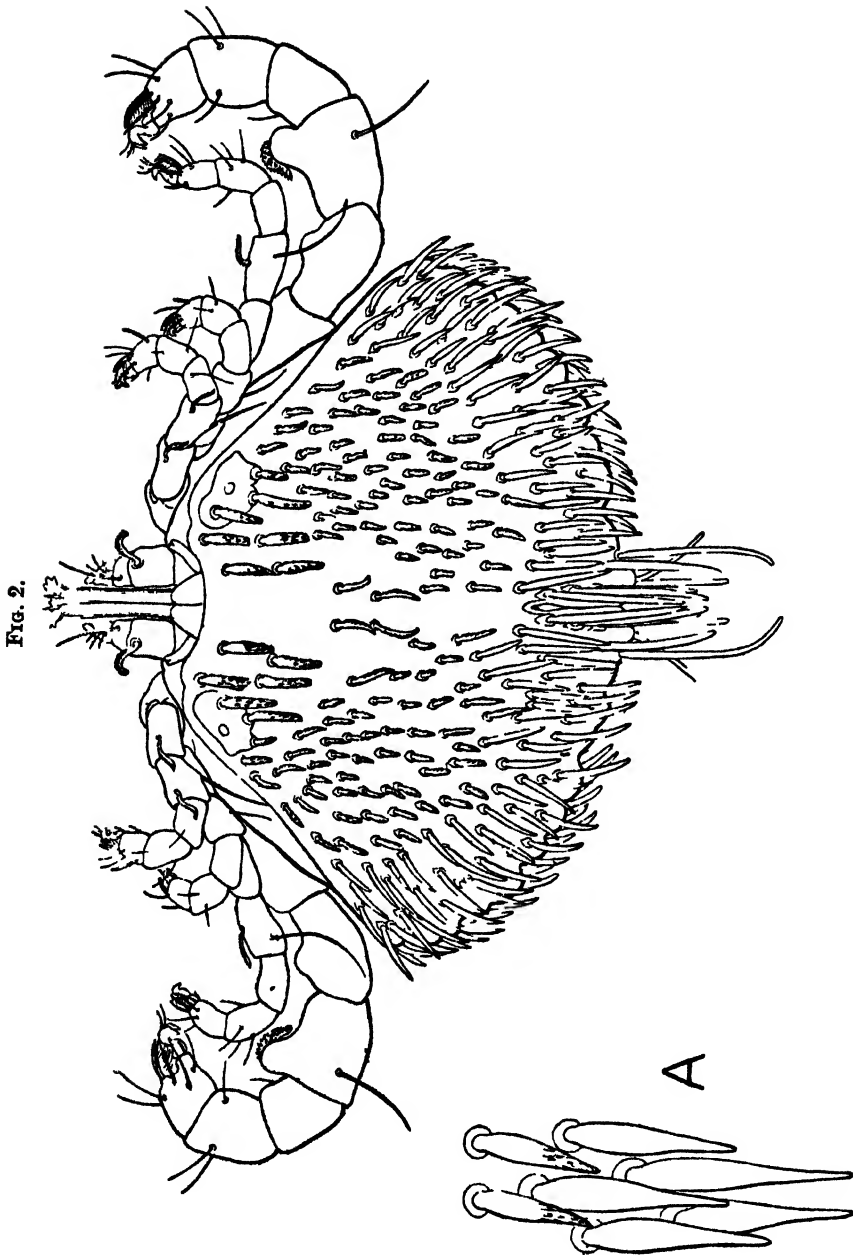
**GECKOBIA AUSTRALIS** Hirst. (Fig. 3.)

Ann. & Mag. Nat. Hist. (8) xix. p. 142 (1917).

♀. Body wider than long. Scutum practically absent. Hairs on the anterior two-thirds of the dorsum much more uniform in size and distribution than in *G. loricata* Berl., none of the front ones being enlarged, all being very short. Posterior hairs longer. Ventral hairs flattened and scale-like, narrow, fan-shaped, and pointed posteriorly ; posterior ones more elongated, however. Hair on dorsal surface of first free segment of palp stout and plumose. Posterior legs longer and stouter than the anterior pairs, the fourth pair being the largest. Coxal spurs large and curved ; there is also a plumose seta on the posterior trochanters and on the femur of the fourth leg.

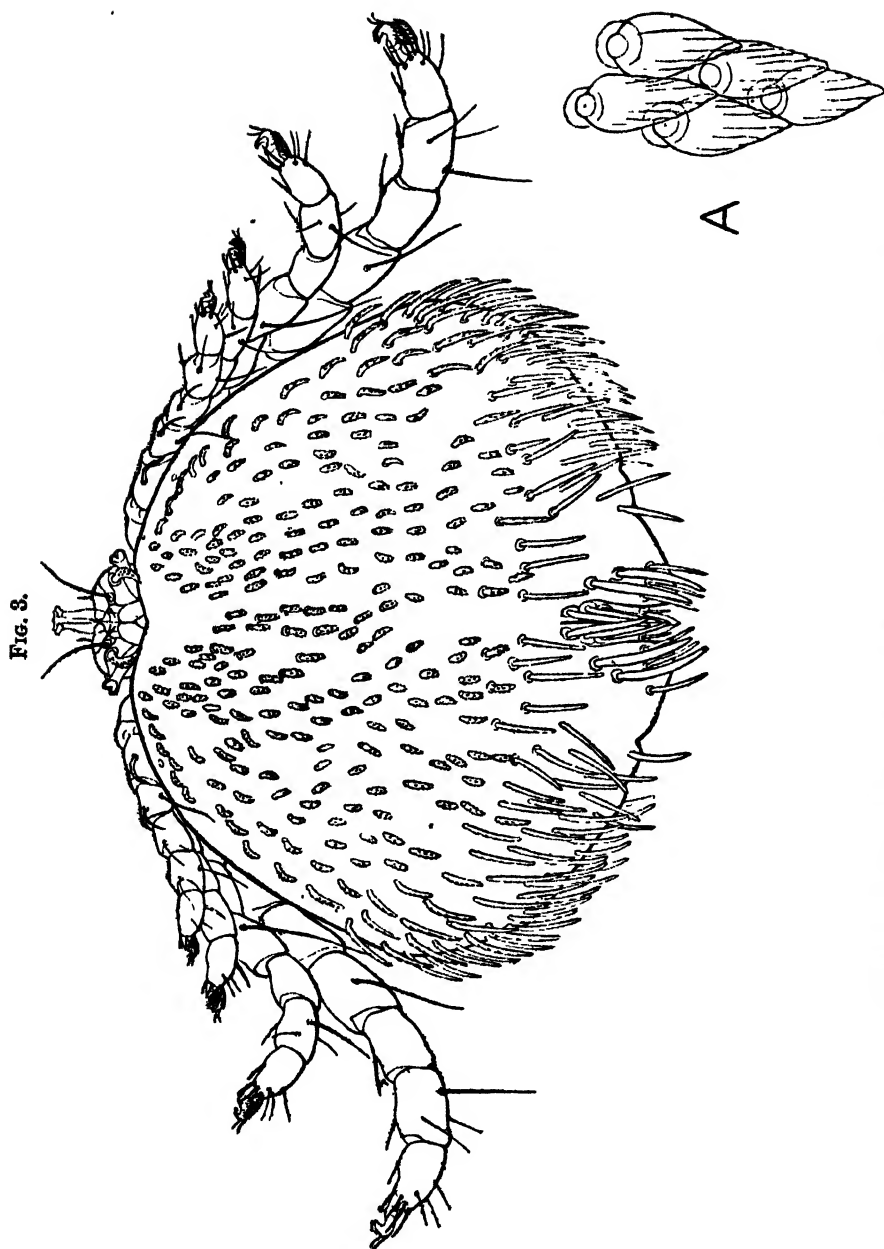
*Length* of body .36 mm. ; its width .425 mm.

*Habitat.* Beira, Portuguese East Africa ; under ventral scales of *Lygodactylus capensis*.



A. Ventral setae, enlarged.

*Geckobia papuana* Hirst, ♀. Dorsal view.



*Geckobia australis* Hirst, ♀. Dorsal view. A. Ventral scales, enlarged.

**GECKOBIA BOULENGERI** Hirst. (Fig. 4.)

Ann. &amp; Mag. Nat. Hist. (8) xix. p. 141 (1917).

♀. Body longer than wide, being widest behind the last pair of legs. Scutum shaped as figured and furnished with ten short stout plumose setæ, arranged along the anterior and lateral margins. Behind the scutum there are numerous very short but fairly slender setæ, whilst posteriorly there are slender elongated hairs or setæ which are not plumose. Venter densely furnished with slender elongated hairs. Legs of third and fourth pairs longer than the anterior ones and swollen, especially those of the fourth pair, which are very stout. Spurs on coxæ strong; trochanter and femur of fourth leg also each with a strong spur. Hair on first free segment of the palp short, stout, and plumose distally.

*Length* of body .47 mm.; its width .43 mm.

*Habitat.* Yunnan Fu, China; on *Gehyra yunnanensis*.

**GECKOBIA MALAYANA** Hirst. (Fig. 5.)

Ann. &amp; Mag. Nat. Hist. (8) xix. pp. 140 &amp; 141 (1917).

♀. Body much wider than long, the scutum seems to be divided into two fairly large portions, separated from one another by a short space [possibly this is merely due to corrosion due to the action of the caustic potash used in preparing the specimens]. In addition to the minute and inconspicuous eye, each half of the scutum bears anteriorly a group of five stout plumose setæ and posteriorly there is another similar seta. Behind the scutum there are numerous very short plumose setæ. Posteriorly there are some slender elongate hairs or setæ. Hairs on venter mostly long and fine.

*Length* of body .28 mm.; its width .49 mm.

*Habitat.* Jalor Caves, Malay Peninsula; on *Gymnodactylus pulchellus*.

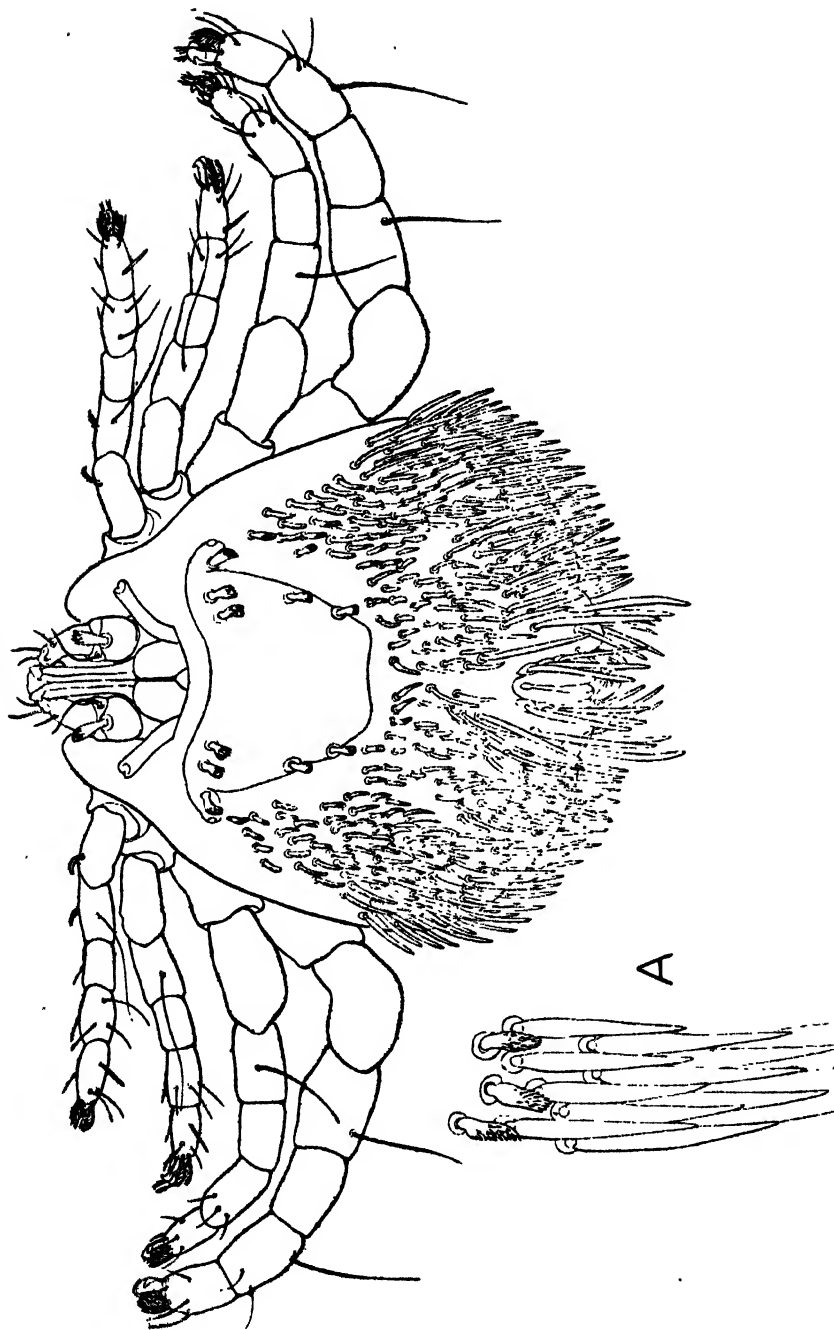
**GECKOBIA GEHYRÆ**, sp. n.

♀. Body wider than long. Scutum apparently absent. There are two groups of hairs anteriorly as in *G. malayana*, but these hairs are not so stout, differing from the hairs in the middle of the dorsum chiefly in being considerably longer. The greater part of the rest of the dorsum is furnished with numerous short slender hairs, but they are not so short as in *G. malayana*. Comparatively long and slender hairs are present near the hinder end. Hairs on venter very like those of *G. malayana*, being fine and elongated. Fourth leg greatly enlarged, being much larger than in *G. malayana*. Spurs on coxæ well developed; trochanter and femur of fourth leg also each with a spur, that on the femur being of large size. Claws of this leg with a very minute denticle dorsally as in *G. malayana*, *G. papuana*, etc.

*Length* of body .26–.27 mm.; its width .31–.34 mm.

*Habitat.* On gecko (*Gehyra oceanica*), Santo, New Hebrides. Several specimens of this species of mite collected by Mr. H. W. Parker.

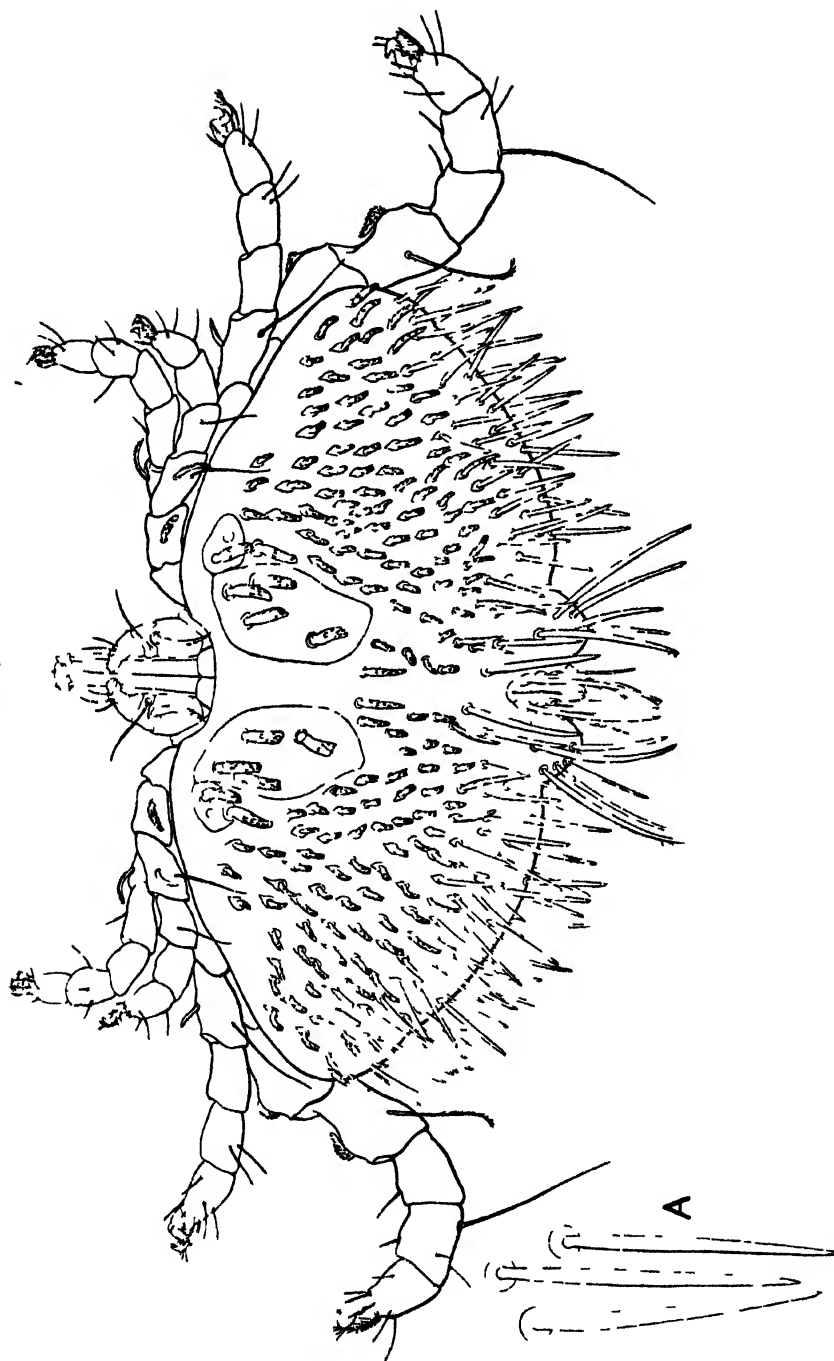
FIG. 4.



*Geckobia boulengeri* Hirst, ♀. Dorsal view.

A. Ventral setae, enlarged.

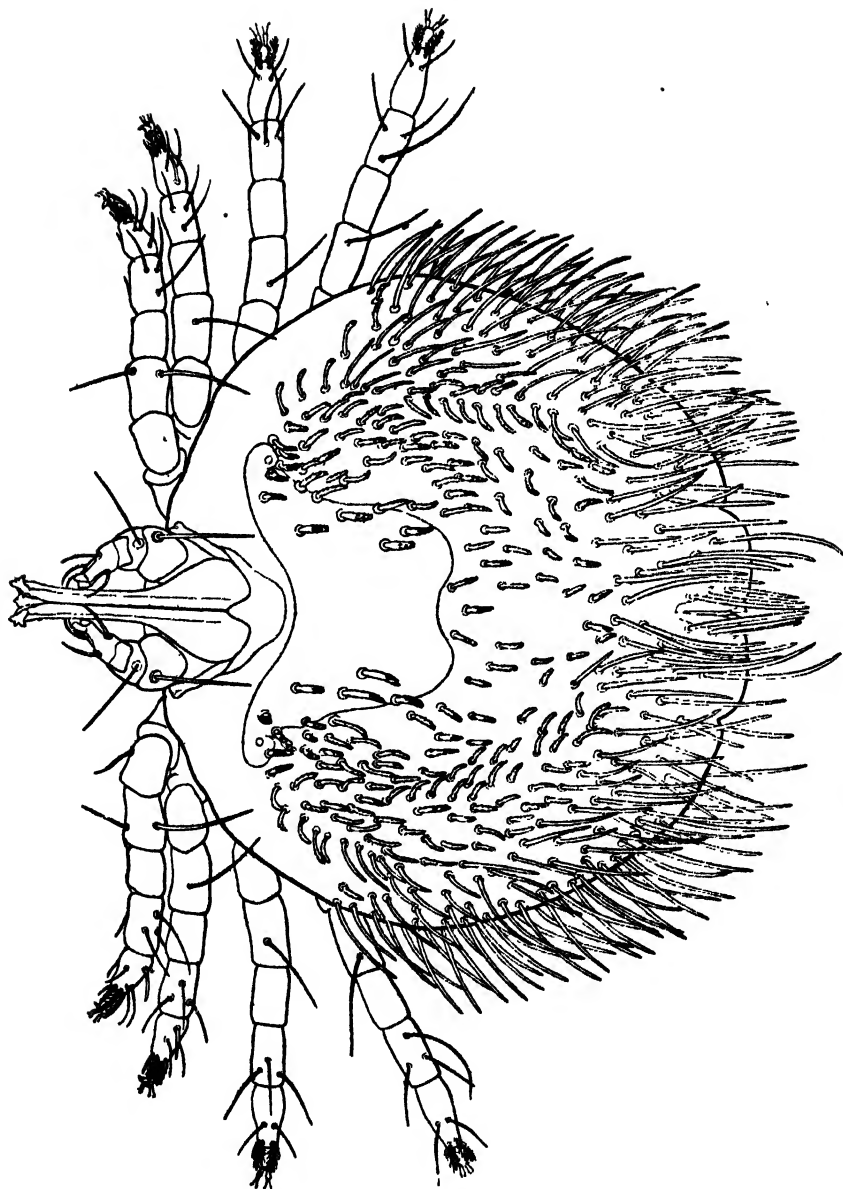
FIG 5



*Gerckobia malayana* Hirst. ♀. Dorsal view.

A Ventral setæ, enlarged.

FIG. 6.

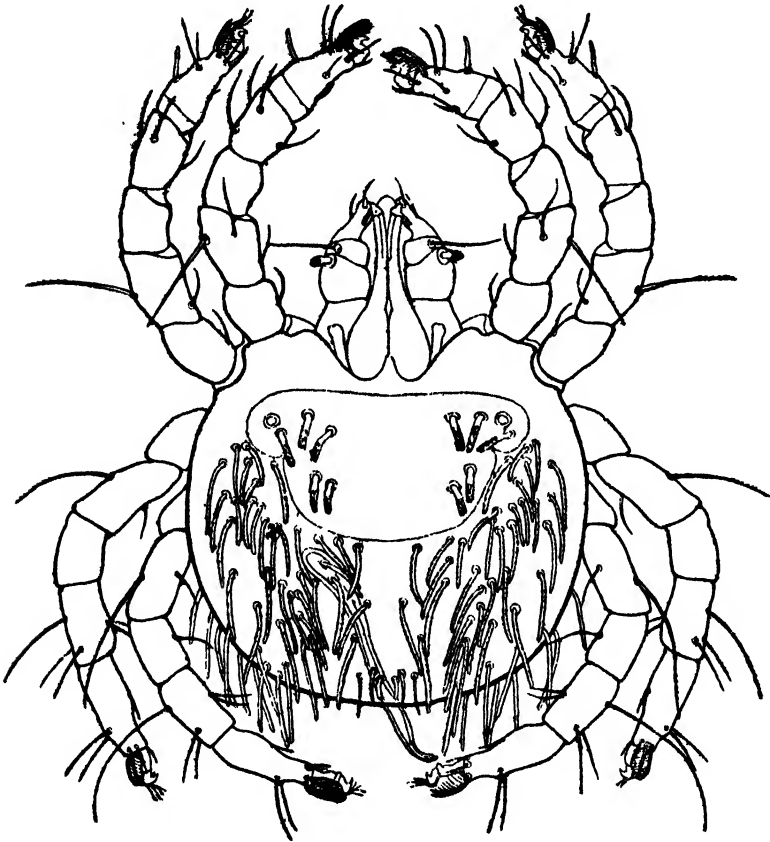
*Geckobia diversipili*, sp. n., ♀. Dorsal view.



*GECKOBIA DIVERSIPILIS*, sp. n. (Figs. 6 & 7.)Heteromorphic form of *G. hindustanica*?

♀. This form is found between the laminæ of the pads of the foot of *Hemidactylus leschenaulti*, and differs from the form *simplex* (occurring between the pad and the foot of the same host) chiefly in having an area in the middle of the dorsum furnished with quite short setæ (whereas in *G. simplex* all the setæ on the dorsum are fairly long and slender, except a few anterior ones). Hairs on venter similar to those on the dorsum instead

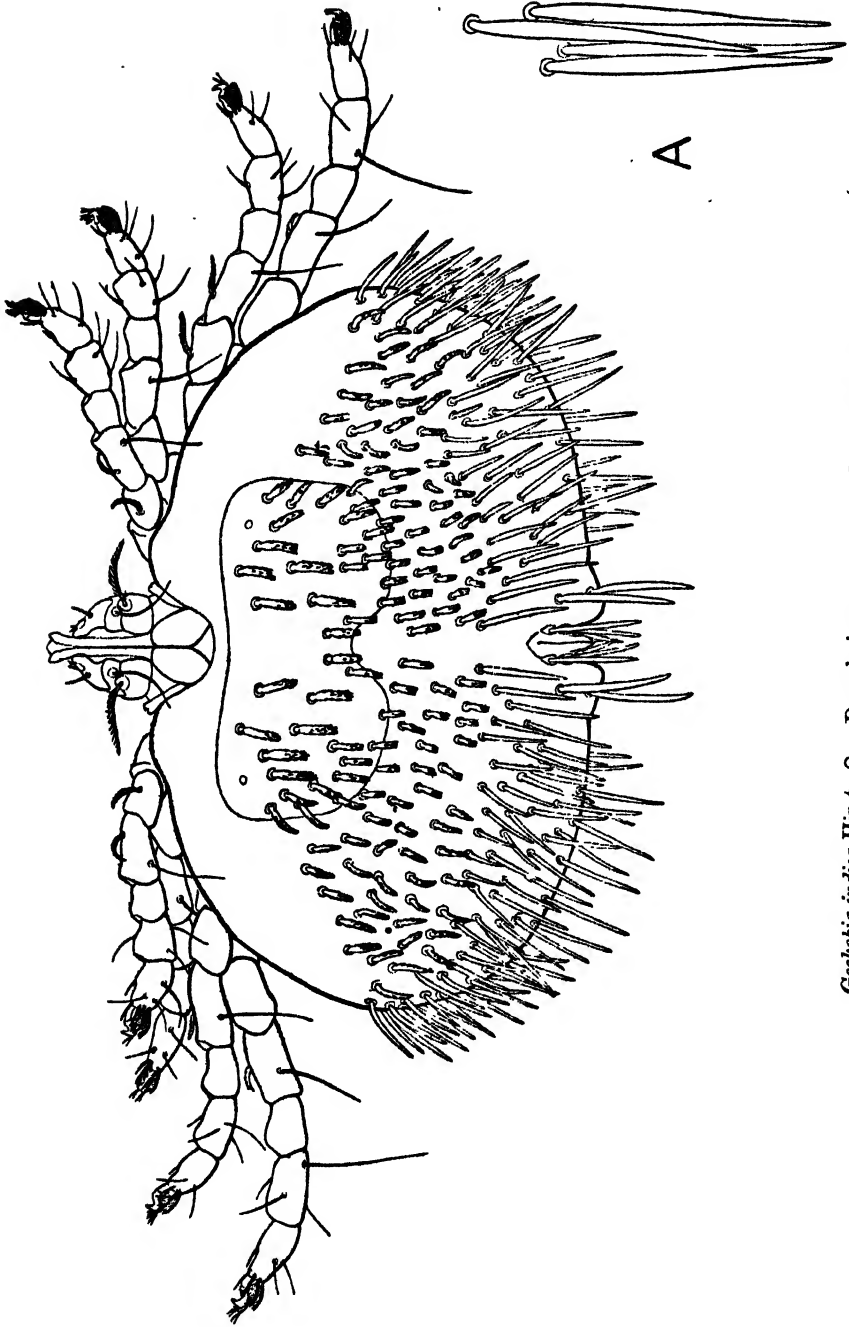
FIG. 7.

*Geckobia diversipilis*, sp. n., ♂. Dorsal view.

of being scale-like as in *G. hindustanica*; anteriorly these ventral hairs are quite short, but posteriorly they are longer. Hair on dorsal surface of first and second segments of palp very fine and not plumose. Body practically spherical in shape as in *G. simplex*.

♂. We have a single male specimen found between the laminæ of a pad

FIG. 8.



*Geckobia indica* Hirst, ♀. Dorsal view. A. Ventral setae.

on the toe of *Hemidactylus leschenaulti* and presumably referable to *G. diversipilis*. In this specimen the scutum has only a few setæ on its surface as in the female, but its posterior margin is not concave. First free segment of palp with a 'short but very stout seta on its dorsal surface. Penis long and shaped as figured.

*Measurements* :—♀. Length of body .45–.50 mm. ; its width .50–.52 mm.

*Habitat and host*. Ganjam, Madras Presidency, and Penang ; specimens from between laminæ of pads of *Hemidactylus leschenaulti*.

### GECKOBIA INDICA Hirst. (Fig. 8.)

Ann. & Mag. Nat. Hist. (8) xix. pp. 189–140 (1917).

♀. Body much wider than long. Scutum transversely elongated, its posterior margin being divided into two rounded lobes by a slight median indentation. Hairs on scutum rather numerous ; they are fairly thick and short, especially the posterior ones. Immediately behind the scutum there are numerous similar very short hairs. Posteriorly the hairs are longer and not distinctly plumose. Hairs in middle of venter long, slender, and pointed. Spurs on ventral surface of coxæ strongly developed. Fourth leg the longest, but it is not swollen. Hair on dorsal surface of first free segment of palp slender, distinctly plumose, and not very long.

*Length* of body .24 mm. ; its width .375 mm.

*Habitat*. Upper Sind ; under ventral scales of *Hemidactylus gleadowi* (= *H. brooki*).

### GECKOBIA LATASTI Ménézin.

♀. Body spherical. Scutum reduced to two minute patches or platelets, which are inconspicuous and easily overlooked. Each of these little platelets bears an eye and two rather long hairs. Between these two platelets there is a pair of short and rather stout plumose hairs. Rest of the dorsum with numerous fairly long slender plumose hairs. Hairs on venter slender and unmodified, being very similar to those on the dorsum ; scales are absent. Spurs on ventral surface of coxæ not very stout. Hair on dorsal surface of first free segment of palp very fine.

*Host*. *Tarentola mauritanica* ; between the toes.

### GECKOBIA GLEADOVIANA, sp. n. (Fig. 9.)

Heteromorphic form of *G. indica* ?

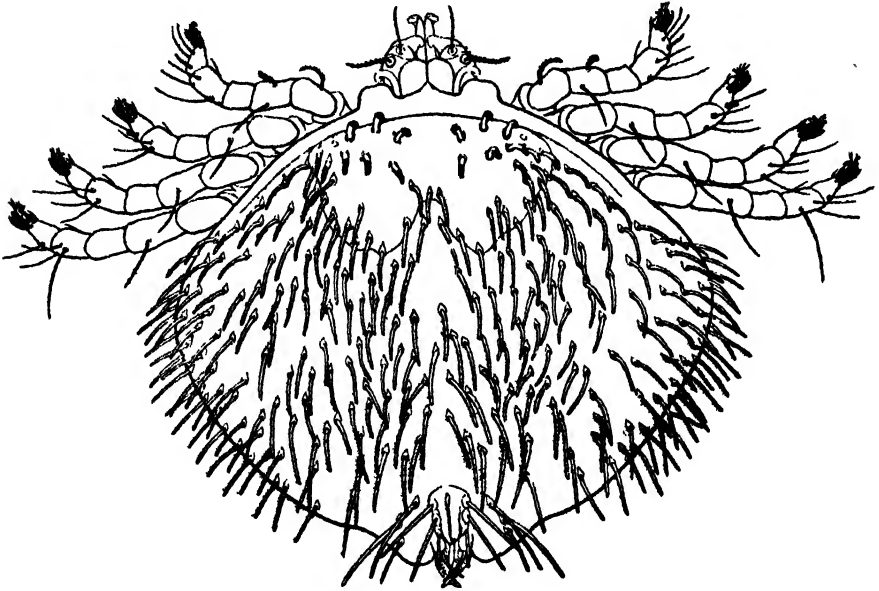
♀. This form, found between the claw and pad of the foot of *Hemidactylus gleadowi*, is very like *G. simplex*, found in the same position on the foot of *H. leschenaulti*, but the seta on the dorsal surface of the first free segment of the palp is longer and much more slender. As in *G. simplex*, all the hairs on

the dorsum are fairly long and slender, except some of the anterior ones. Hairs at posterior end of body (near anus) longer than in *G. simplex*. Ventral hairs similar to those on the dorsum, scales being absent. Spurs on coxæ shorter and stronger than in *G. simplex*. Body almost spherical in shape.

*Length of body* .38 mm. ; *its width* .44 mm.

*Habitat and host.* Upper Sind ; between claw and pad of *Hemidactylus gleadowi* (= *H. brooki*).

FIG. 9.



*Geckobia glendoviana*, sp. n., ♀. Dorsal view.

*GECKOBIA SIMPLEX*, sp. n. ? (Fig. 10.)

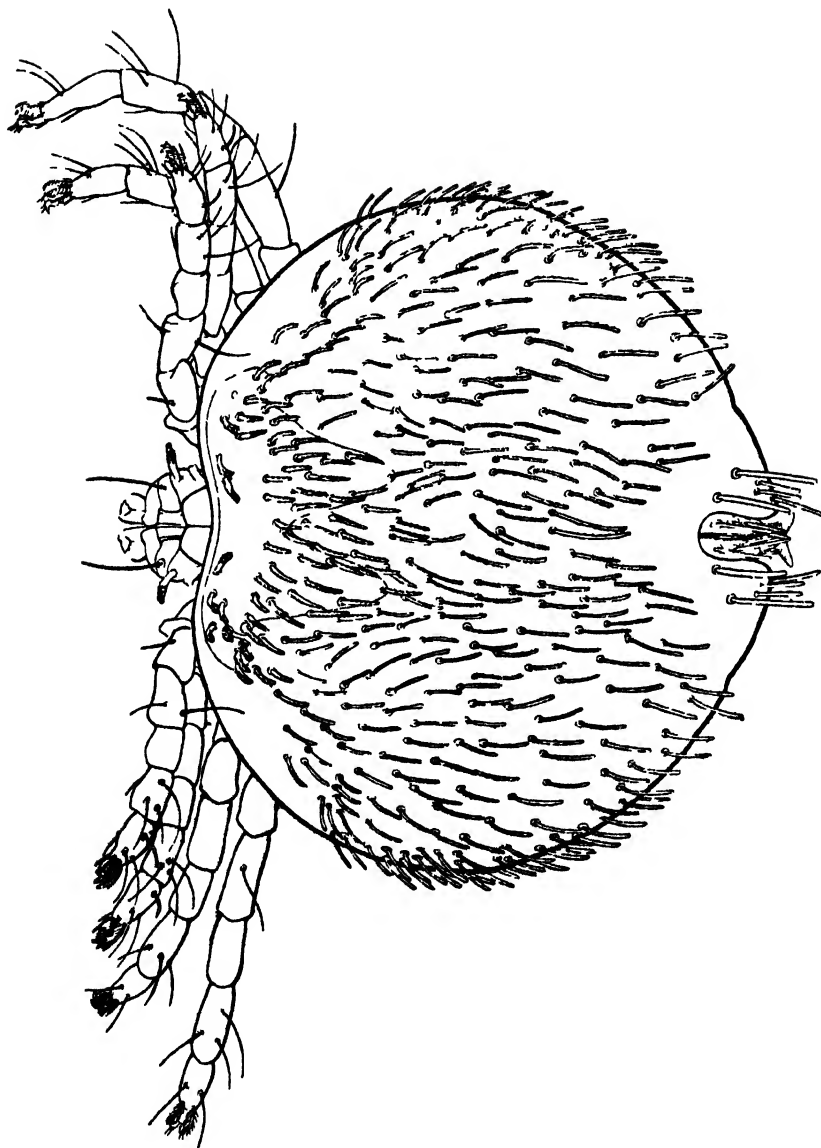
= *G. similis* Trägårdh ? (heteromorphic form of *G. hindustanica* ?).

♀. This form, found between the toe and pad of *Hemidactylus leschenaulti* as mentioned above, differs from the two other forms found on this species of lizard in having all the hairs on the dorsum fairly elongated and slender, except for a few anterior hairs. Hairs on venter very similar to those on the dorsum, and not scale-like as they are in *G. hindustanica*. Hair on dorsal surface of first segment of palp stout and plumose. Body sometimes a little wider than long, but others are practically spherical in shape.

*Length of body* .30-.37 mm. ; *its width* .31-.45 mm.

*Habitat and host.* Between toe and pad of *Hemidactylus leschenaulti* ; Godaveri Valley, Madras.

FIG. 10.

*Geckobia simplex*, sp. n. ♀. Dorsal view.

**GECKOBIA HINDUSTANICA, sp. n. (Fig. 11.)**

♀. This form lives beneath the ventral scales of *Hemidactylus leschenaulti*, and is distinctly wider than long (the specimen figured is shown a little too wide). Anterior setæ on dorsum, especially those on the scutum, quite short and plumose; behind them comes an area occupied by numerous still shorter setæ; posterior margin of dorsum with numerous elongated setæ or hairs. Most of the hairs on the venter, especially those in the middle, are flattened and scale-like, the ends being sharply pointed. Spurs on ventral surface of coxæ much stouter than in *G. simplex*. Seta on dorsal surface of first segment of palp short, stout, and plumose.

*Length* of body .25 mm.; its width .38 mm.

*Habitat and host.* *Hemidactylus leschenaulti*; specimens from under the ventral scales of this host at the Godavari Valley, Madras; also Ceylon and Ganjam.

It is possible that the species described above is a form of *G. similis* Trägårdh, for I have found specimens on the same host as his species, viz. *Hemidactylus turcicus*, Island of Shadwan. Trägårdh states, however, that ventral scales are absent in his specimens of *G. similis*, so it is possible that he was dealing with quite a different species.

**GECKOBIA SOCOTRENSIS Hirst. (Fig. 12.)**

*Ann. & Mag. Nat. Hist.* (8) xix. pp. 141 & 142 (1917).

♀. Body wider than long. Scutum indistinct, but a narrow transverse strip of chitin can sometimes be distinguished near the anterior margin? Greater part of dorsum furnished with short slender slightly plumose hairs, none of them being especially enlarged. Posteriorly there are some longer hairs. Scales on venter narrower than in *G. tarantulæ* Trgdb. and sharply pointed, the point sometimes being rather elongated. Spurs on coxæ well developed. Legs slender, the fourth pair the longest. Hair on first segment of palp not very slender, plumose.

*Length* of body .3 mm.; its width .37 mm.

*Habitat.* Socotra; on *Pristurus rupestris*.

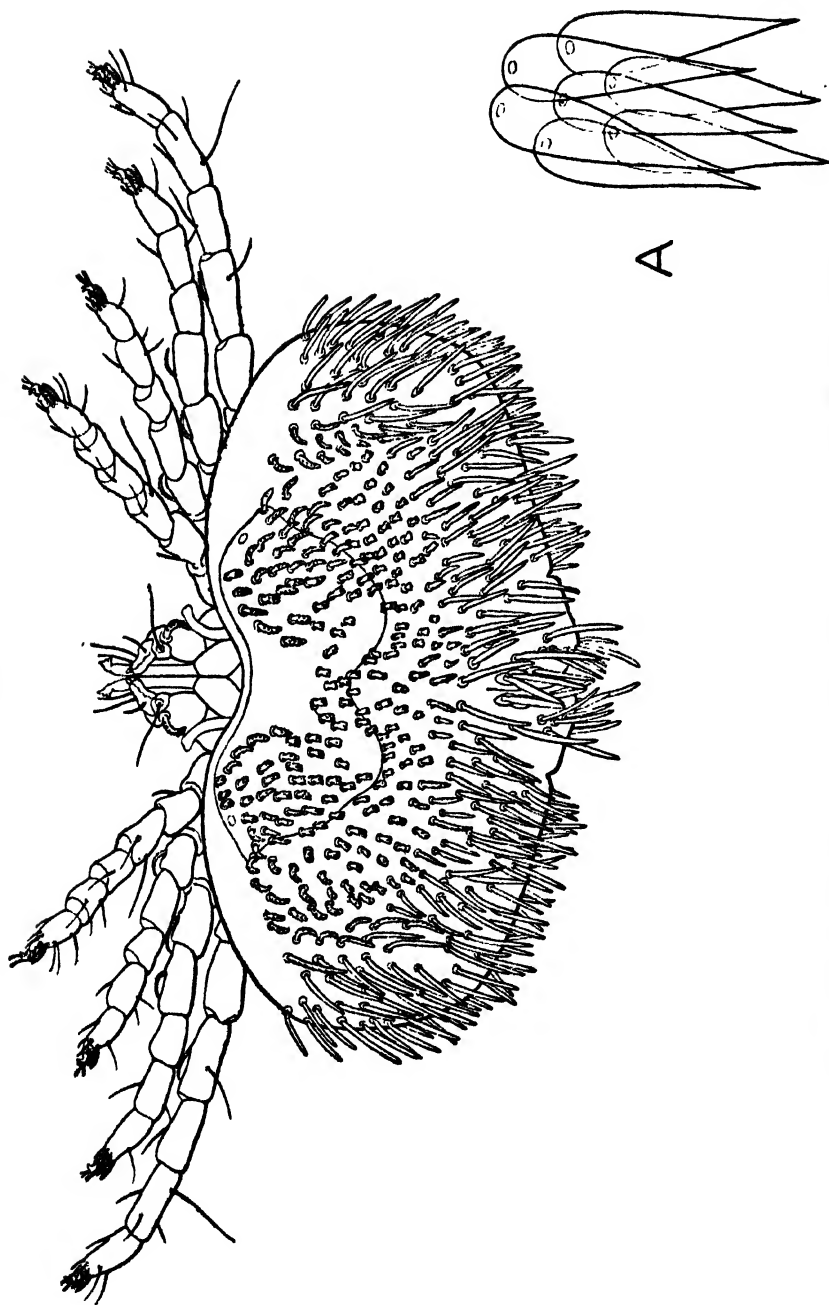
**GECKOBIA TARANTULÆ Trägårdh.**

Jägerskiöld, Swedish Zool. Exp. Egypt, part 2, p. 46, t. 3. figs. 14, 19-35.

♀. Body not very much wider than long. Scutum ill-defined, the hairs or setæ on it are not much stouter than the other hairs on the dorsum. Hairs on dorsum fairly elongated but not long, and none are very stout. Hairs in middle of venter fan-shaped, being more elongated than in *G. loricata* and *G. turkestanæ*. Spurs on coxæ rather slender. Hair on dorsal surface of first segment of palp rather slender and plumose.

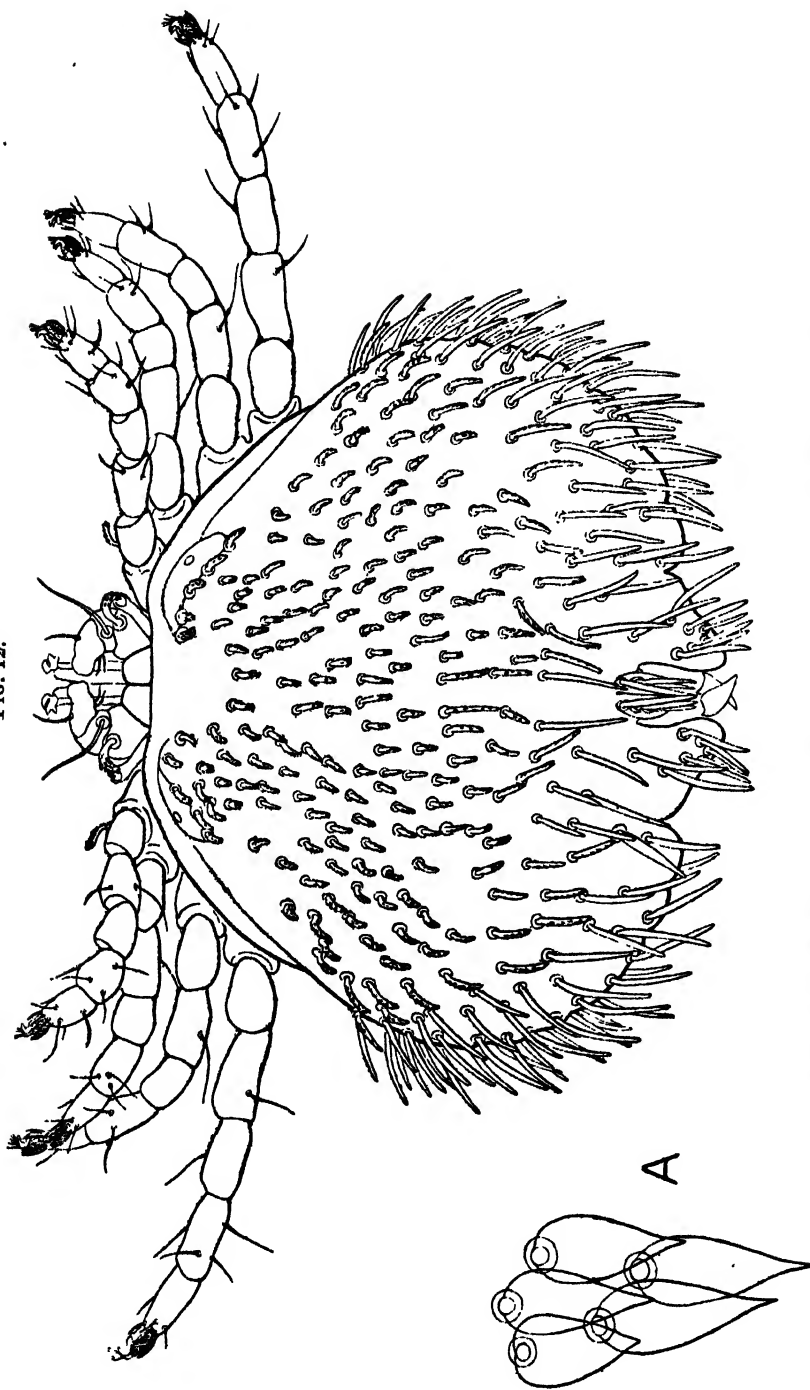
*Host.* *Tarentola annularis*; Egypt.

FIG. 11.



*Geckobia hindustanica*, sp. n., ♀. Dorsal view. A. Ventral scales, enlarged.

FIG. 12.



*Geckobia socotrensensis* Hirst, ♀. Dorsal view. A. Ventral scales, enlarged.



**GECKOBIA LORICATA** Berlese.Heteromorphic form of *G. latasti* Mégnin?*G. loricata* Berlese, Acar., etc., in Italia rep. Fasc. lxi. no. 2 (1892).

♀. Body wider than long. As in *G. latasti*, the scutum is reduced to a minute patch or platelet on each side of the anterior end of the dorsum, bearing the usual eye and also two hairs. On each side close to the scutum there is a batch of large stout plumose setæ; posteriorly in the middle of the scutum there is a zone occupied by very short stout plumose setæ; posteriorly to these there are numerous fairly long slender plumose setæ or hairs. Scales on middle of venter short and wide, being very like those in *G. turkestanica*. Spurs on ventral surface or coxæ very large; trochanters of posterior legs also with weaker spurs. Hair on dorsal surface of first segment of palp very slender, but the distal part of it distinctly plumose.

*Host. Tarentola mauritanica*; under ventral scales.

**GECKOBIA TURKESTANA**, sp. n. (Fig. 13.)

♀. Body considerably wider than long. Scutum distinct, posterior margin concave in the middle. Twelve plumose hairs are present on the scutum; they are of moderate thickness, the anterior ones being shorter than the others; all the other hairs on the dorsum are fairly elongated, slender, and plumose. Hairs on venter mostly flattened and scale-like; they are short and wide (heart-shaped), being wider than in *G. tarantula*; some of the posterior ones are more elongated however, being oval or fan-shaped. Hair on first segment of palp very slender, plumose, and of moderate length. Posterior legs longer than the anterior ones, but not swollen. Coxal spurs fairly well developed, being thicker than in *G. tarantula*.

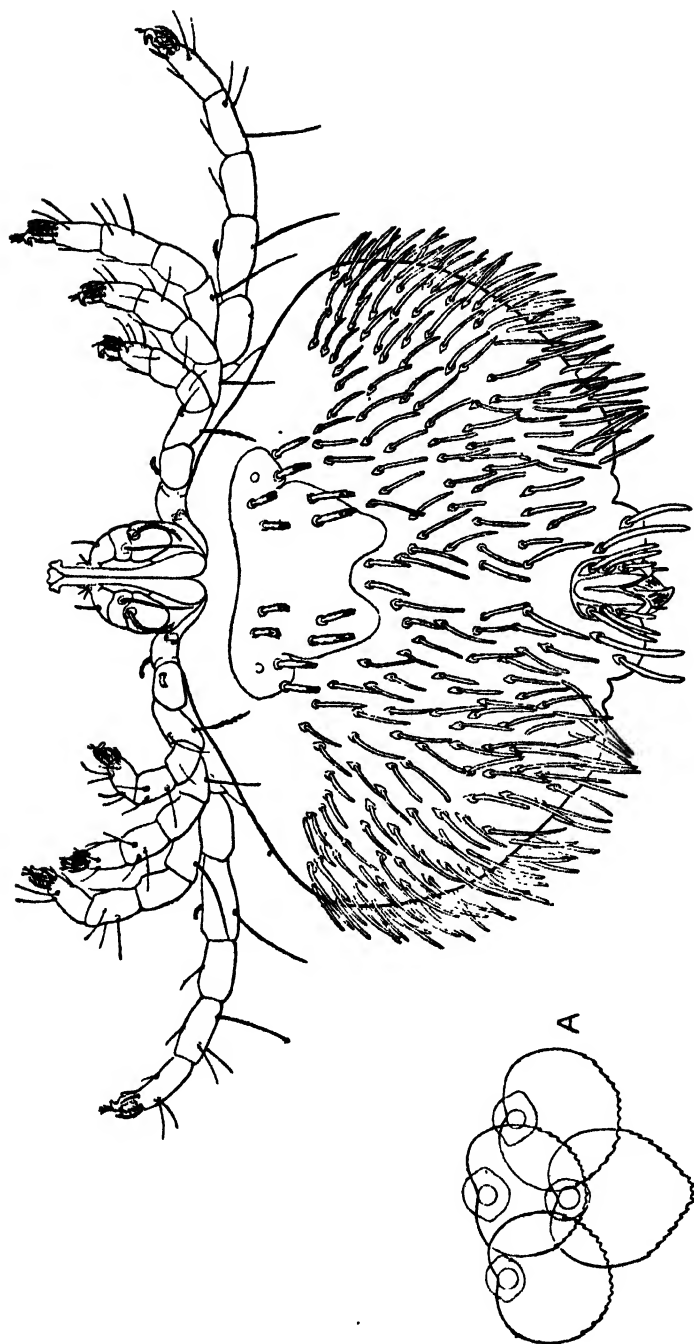
*Length* of body 35–38 mm.; its width 50–55 mm.

*Habitat.* Tschinas, Turkestan; under scales of leg and tail of *Gymnodactylus russovi*.

The principal differences between the genera *Pterygosoma* and *Geckobia* may be tabulated as follows:—

{	Scutum absent. Body very much wider than long. Dorsum in the middle with only two pairs of hairs. Posterior margin with the hairs arranged in a single or double series and two anal tufts. Only a few pairs of hairs on the venter.....	Genus <i>PTERYGOSOMA</i> Peters (syn. <i>Eupterygosoma</i> Trägårdh).
	Scutum usually present. Body usually not nearly so wide, sometimes spherical. All the dorsum with numerous hairs. Hairs on posterior margin very numerous and not very regularly arranged. Hairs on venter very numerous.....	Genus <i>GECKOBIA</i> Mégnin.

FIG. 13.



*Geckobia turkestanica*, sp. n., ♀.

A. Ventral scales, enlarged.

## Genus PTERYGOSOMA Peters.

*Key to the Species of Pterygosoma Peters (females).*

1. { Hairs on posterior margin of body wide and flattened, being paddle-shaped ..... *P. melanum* Hirst.
1. { Hairs on posterior margin unmodified or with the tip only flattened..... 2.
2. { All the hairs on the posterior margin pointed..... *P. persicum* Hirst.
2. { Some of the hairs on the posterior margin with the tips flattened. 3.
3. { Marginal hairs short and few in number ..... *P. inermis* Trädg.
3. { Marginal hairs longer and more numerous ..... 4.
4. { All the marginal hairs with the distal ends enlarged and flattened. *P. agamæ* Peters.
4. { Anterior (lateral) marginal hairs with the ends pointed. Posterior marginal hairs with the ends flattened ..... *P. neumanni* Berl.

## PTERYGOSOMA AGAMÆ Peters. (Fig. 14.)

*P. agamæ* Peters, Berlin Sitzber. Ges. natf. Freunde, June 1849 (Vossische und Spener'sche Zeitung).

*P. agamæ* Karsch, MB. Ak. Berlin, p. 336, pl. 1. fig. 9 (1878).

♀. Body transversely elongated, being much wider than long. Anterior hairs on dorsum slender and longer than in *P. neumanni* etc. These little anterior hairs are numerous, reaching practically as far as the point where the fringe of long marginal posterior hairs commences. At the inner end of each of the two patches of these little hairs the hairs are rather crowded together, but they are sparser laterally. The posterior of the two pairs of hairs in the middle of the dorsum has the distal end flattened and enlarged. There is a continuous series of rather long slender hairs with spatulate ends along the posterior margin of the body. Upper anal hairs short and with the distal ends flattened and unusually wide.

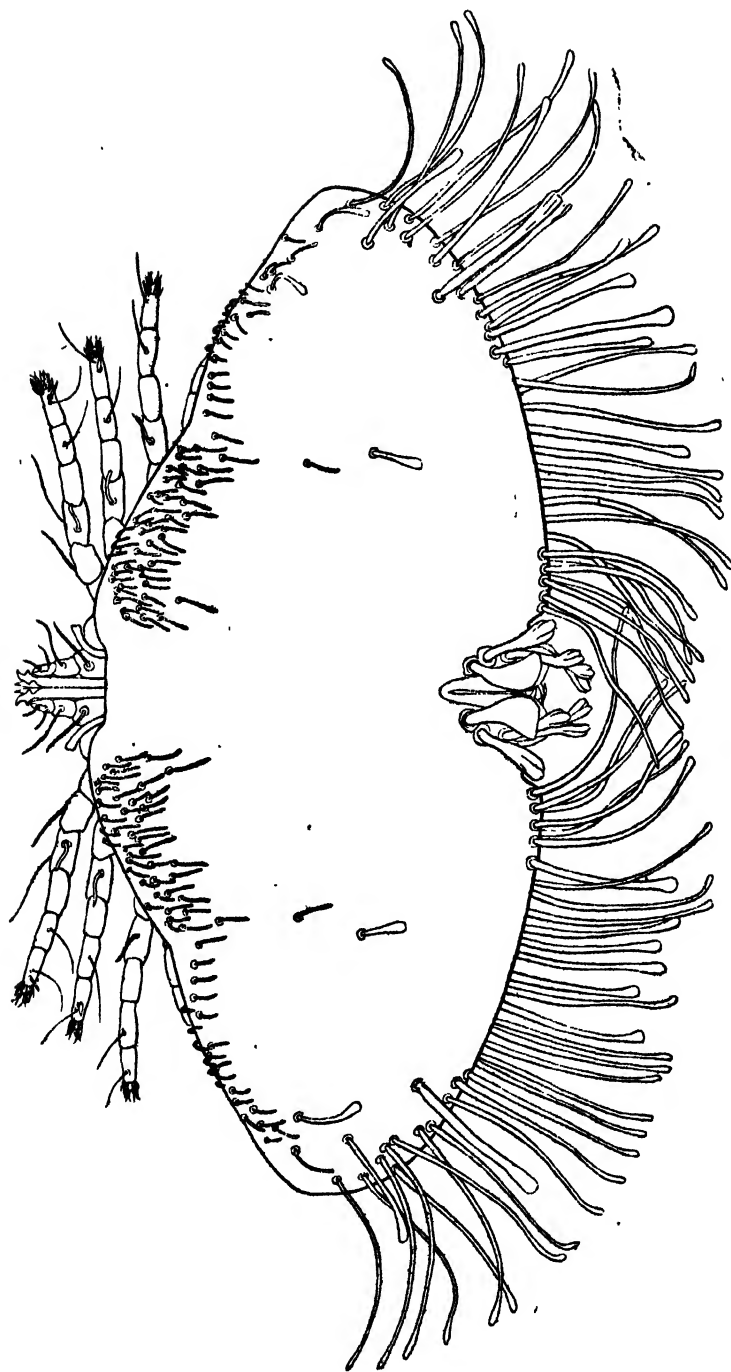
*Habitat.* Peters's specimens were from *Agama mossambica* Peters. The British Museum has examples from the same host taken at Beira, Portuguese East Africa.

## PTERYGOSOMA NEUMANNI (Berlese). (Fig. 15.)

*Geckobia neumanni* Berlese, Redia, vi. p. 347 (1910).

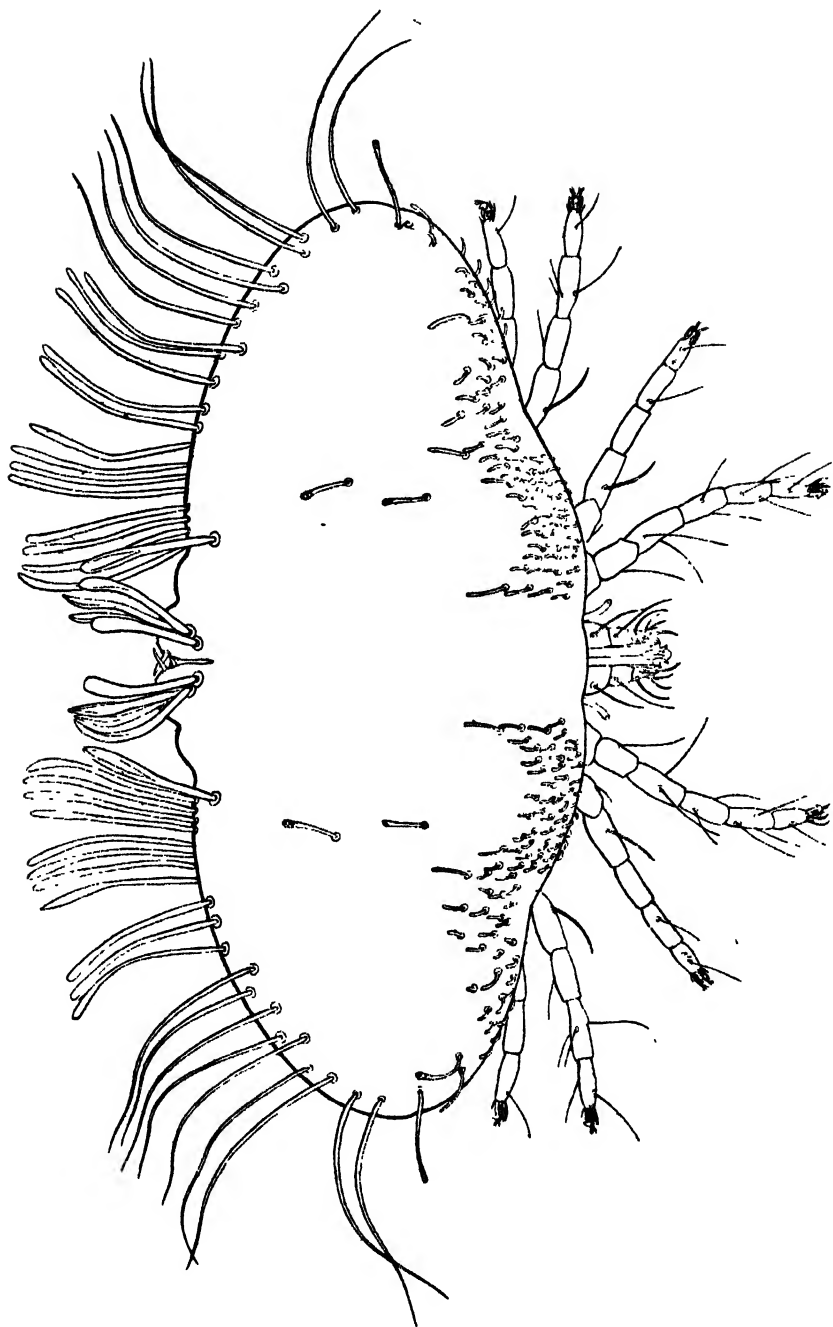
♀. Closely allied to *P. agamæ* Peters, but the long lateral setæ at the beginning of the marginal fringe have the ends pointed, thus differing from the more posterior ones, which have the tips slightly enlarged and flattened (whereas in *P. agamæ* all the marginal hairs, even those at the beginning of the fringe, have the tips slightly enlarged and flattened). Little anterior hairs of dorsum shorter than in *P. agamæ*. Dorsal setæ of anal tuft narrower than in that species.

FIG. 14.



*Pterygosoma agame* Peters, ♀. Dorsal view.

FIG. 15.

*Pterygosoma neumanni* Berl., ♀. Dorsal view.

*Habitat.* Berlese's specimens of this species were from *Agama colonorum*; Senegal. The British Museum has specimens from the same host; G.oli Mountains, Somaliland. Also from *Calotes versicolor*; Madras.

**PTERYGOSOMA INERMIS** (Trägårdh).

*Geckobia* (*Eupterygosoma*) *inermis* Trägårdh, in Jägerskiöld, Swedish Zool. Exp. Egypt and White Nile, part 2, pp. 59-63, pl. 3. figs. 11-13, 15-18, 36-38 (1905).

♀. Body much wider than long. Anterior hairs on dorsum few in number and slender. Posterior pair of hairs in middle of dorsum with the ends well expanded. Posterior margin lacking the usual fringe of long hairs, but there are some comparatively short lateral marginal hairs with their tips slightly flattened and expanded. Three or four pairs of not very long setæ are also placed round the anal orifice.

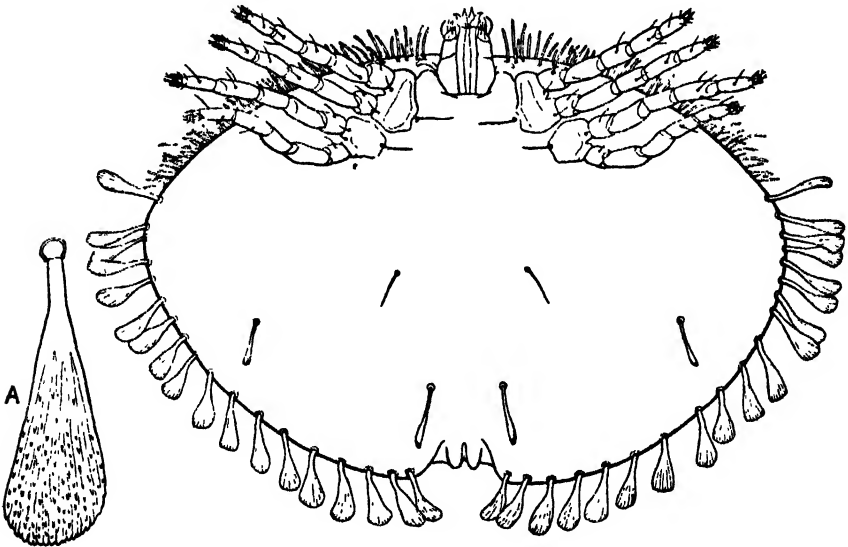
*Habitat.* Specimens from Cyprus and Ghizeh found on *Agama stellio*.

**PTERYGOSOMA MELANUM** Hirst. (Fig. 16.)

*Pterygosoma melanus* Hirst, Ann. & Mag. Nat. Hist. (8) xix. p. 137 (1917).

♀. Body considerably wider than long, but the length is greater than is usual in this genus. On each side of the dorsum anteriorly there is a fairly

FIG. 16.



*Pterygosoma melanum* Hirst, ♀. Ventral view.

A. Marginal hair, enlarged.

elongated patch of the short slender plumose hairs. The few hairs of the rest of the dorsum have their distal ends flattened and expanded. Postero-lateral

and posterior margins with a fringe of paddle-shaped hairs, which are flattened and greatly expanded distally. This fringe of modified hairs is continuous on each side of the posterior part of the body, except at the anus. There are about 18–22 of these paddle-shaped hairs on each side.

*Colour* (spirit specimens) usually black, but sometimes paler.

*Length* of body .72 mm.; its width 1.1 mm.

*Habitat*. Deelfontein and Klipfontein, South Africa; under axillæ and ventral folds of neck of *Agama atra*.

#### PTERYGOSOMA PERSICUM Hirst. (Fig. 17.)

*Pterygosoma persicus* Hirst, Ann. & Mag. Nat. Hist. (8) xix. pp. 137–138 (1917).

♀. Body much wider than long. Anterior hairs short, slender, and not very numerous, forming two little patches on each side of the dorsum. Other hairs on dorsum few in number and mostly plain and very fine, but there are four slightly thicker and plumose hairs situated just in front of the posterior margin. Marginal hairs long, very fine, plain, and pointed, being unmodified in any way. Two tufts of similar hairs are also present on each side, not far from the anus.

*Length* of body .6 mm.; its width 1.15 mm.

*Habitat*. Sixty miles north-west of Kermanshaw, Persia; under scales of tail of *Agama nupta*.

#### Genus HIRSTIELLA Berl.

##### HIRSTIELLA TROMBIDIIFORMIS Berl.

*Geckobiella (Hirstiella) trombidiiformis* Berlese, Redia, xiv. pp. 194 & 195 (1920).

♀. Body shaped rather like some of the non-parasitic forms of Trombidiidæ (*Trombidium* etc.), being longer than wide and widest anteriorly. Instead of being furnished with very numerous hairs as in *Geckobiella*, the dorsum has only isolated pairs of hairs. Lateral group of hairs of *Geckobiella* also absent. Scutum apparently absent, but there is a little lateral eye anteriorly. Hairs on venter very few in number. At the hinder end of the body there are a few pairs of longer hair or setæ, a pair near the anus being the longest. Palp with a terminal claw-like spine as in *Geckobiella*.

*Habitat*. Guanajato, Mexico. Host unknown. The above description is based on a couple of mounted specimens kindly presented to the British Museum by Prof. A. Berlese.

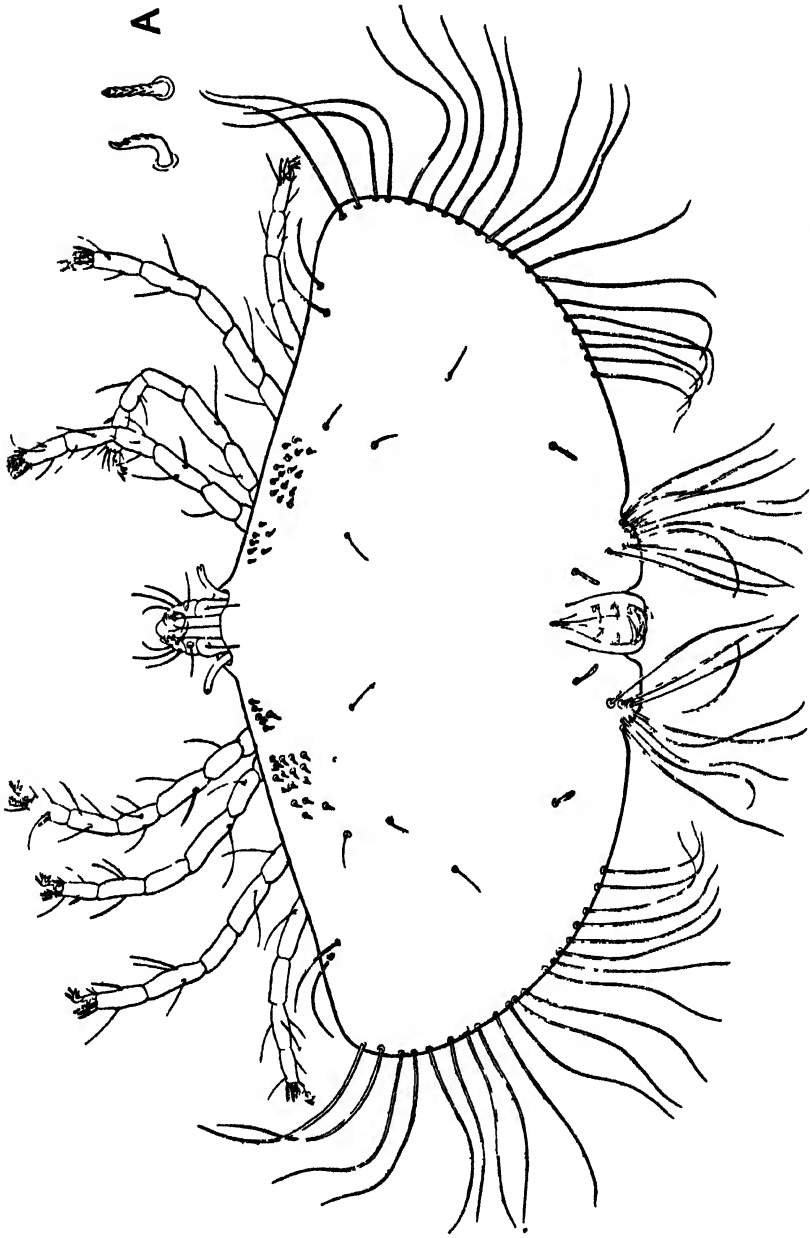
#### Genus PIMELIAPHILUS Trägårdh.

##### PIMELIAPHILUS TENUIPES Hirst. (Fig. 18.)

Ann. & Mag. Nat. Hist. (8) pp. 142 & 143 (1917).

♀. Body oval, being longer than wide. Scutum triangular, and furnished with six long plumose hairs, four of which form a transverse row along the

FIG. 17.

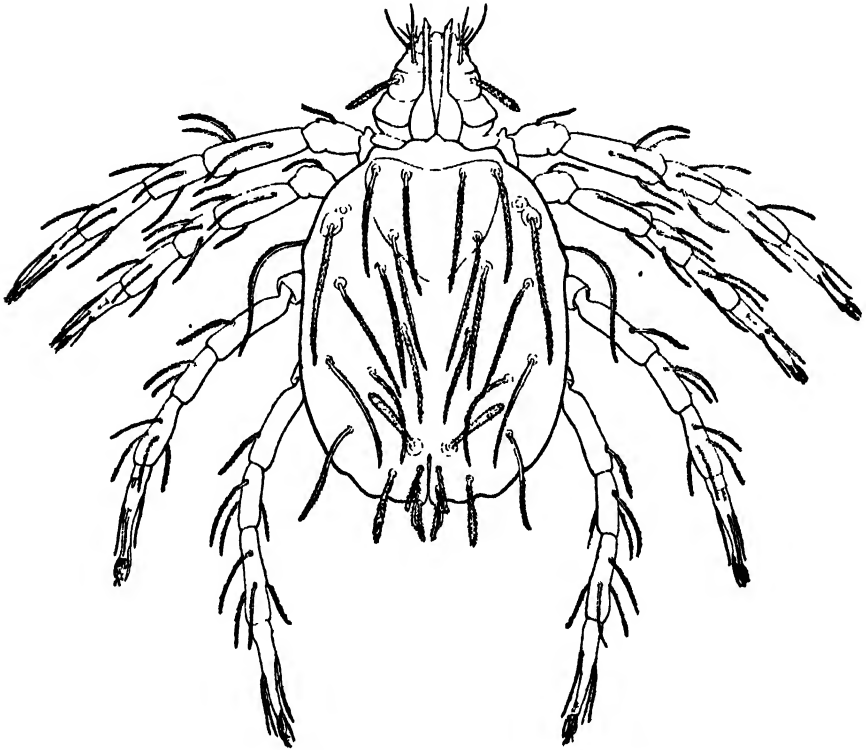


*Pterygosoma persicum* Hirst, ♀. Dorsal view. A. Anterior dorsal hairs, enlarged.



anterior margin, the other pair being situated behind the middle. Hairs on body long, slender, and plumose, not very numerous and arranged as in *P. podapolipophagus* Trgdh. and *P. insignis* Berl. Hairs on venter few in number. Projecting portion of peritremal tube short. Legs long and slender, and furnished with numerous slender plumose hairs.

FIG. 18.



*Pimeliaphilus tenuipes* Hirst, ♀. Dorsal view.

Length of body .274 mm.; its width .22 mm.

*Habitat.* Honda, Magdalena River, Colombia. A single example from *Gonatodes albogularis*.

#### Genus GECKOBIELLA Hirst.

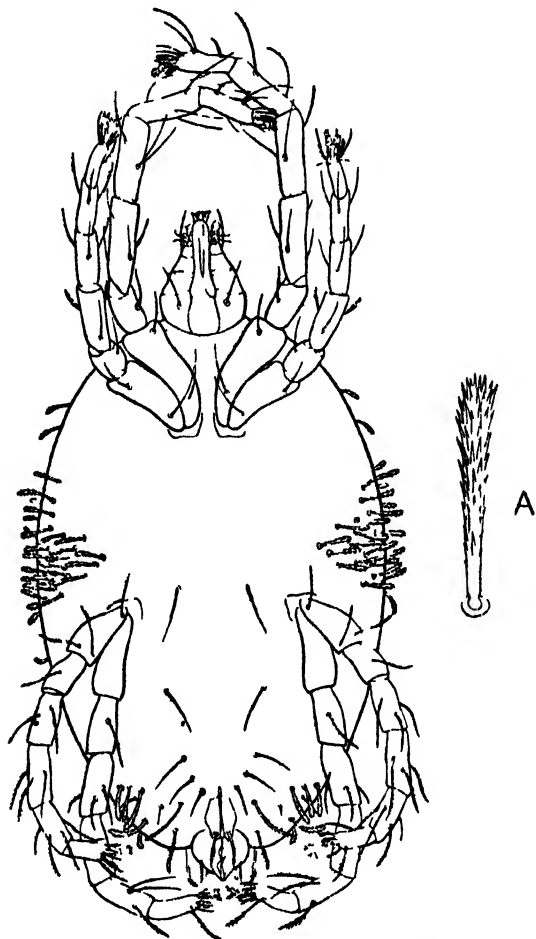
##### GECKOBIELLA TEXANA (Banks). (Fig. 19.)

*Geckobia texana* Banks, Proc. Ent. Soc. Washington, viii. p. 134 (1905).

♀. Body long-oval, being much longer than wide. Scutum apparently absent. Numerous short plumose hairs are present on the dorsum and sides of the body. Venter with only a few hairs. Free portion of peritreme

rather long and directed forwards. Coxæ not nearly so fused together as in *Geckobia* and *Pterygosoma*.

FIG. 19.



*Geckobiella texana* (Banks), ♀. Ventral view.

A. Lateral seta, enlarged.

*Habitat.* Duval county, Texas; on *Sceloporus spinosus* var. *clarkii*. The specimens described by Banks were from *Sceloporus floridanus*.

On some Collembola from Mesopotamia.  
By JAMES MEIKLE BROWN, B.Sc., F.L.S., F.E.S.

(With 31 Text-figures.)

[Read 19th March, 1925.]

THE material described in the present paper was collected by Messrs. P. A. Buxton, M.A., and W. Edgar Evans, B.Sc., in Mesopotamia, chiefly in the neighbourhood of Amara and Bagdad, in 1918. The collection consisted of two tubes of alcohol material from Mr. Buxton and five tubes of similar material from Mr. Evans, including in all some fifteen species of Collembola, which represent, I believe, the first examples of this order of insects taken in that region.

It is noteworthy that all the species obtained, though several are hitherto undescribed forms, belong to well-known European genera, several of the species being, indeed, identical with those commonly occurring in Europe.

I am indebted to Mr. Buxton and to the late Mr. Wm. Evans, of Edinburgh, for the opportunity of examining and reporting on this interesting material.

The types and duplicates of the new species described will, where available, be deposited in the British Museum (South Kensington) and in the Royal Scottish Museum, Edinburgh, respectively.

Order **COLLEMBOLA** Lubbock.

Sub-order **ARTHROPLEONA** Börn.

Family **PODURIDÆ** Lubb.

Genus **ACHORUTES** Templeton.

*Achorutes* Templeton, Trans. Ent. Soc. Lond. 1834, p. 96.

*Hypogastrura* Bourlet, Mém. Soc. des Sci. de l'Agric. de Lille, 1839, p. 404.

„ Börner, Mitth. Naturh. Mus. Hamburg, 1906, p. 156.

*Achorutes* Folsom, Bull. Mus. Comp. Zool. Harvard, 1924, p. 505.

Continental writers have of late years followed Börner in making use of Bourlet's name for this genus, but Dr. Folsom has recently pointed out that this procedure is untenable, and that Templeton's name should stand.

**ACHORUTES TIGRIDIS**, sp. nov.

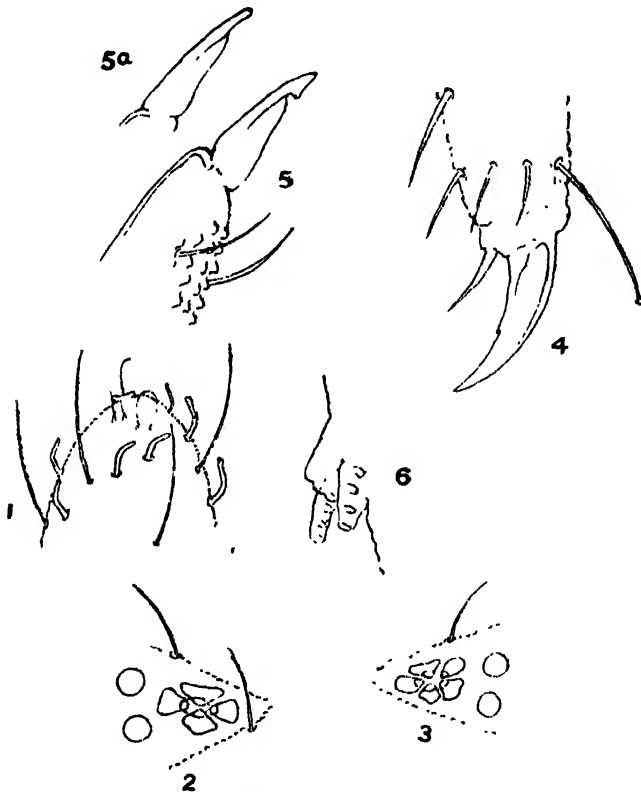
Colour bluish-grey or purplish (in alcohol), mottled. Head rather darker, underside and appendages paler, segment borders pale. Eye-patch dark.

Skin papillæ fine. Hairs sparse, short and stout, longer and more numerous on the posterior abdominal segments, on the antennæ, and especially on the legs. Dorsal hairs obscurely serrated.

Antennæ slightly shorter than the length of the head. The proportional lengths of the segments as 1:1:1.25:1.7. Segment IV with subapical retractile papilla, and 7 curved, scarcely tapering olfactory hairs, 2 inner, 3 upper, and 2 outer. (Fig. 1.)

Eyes 8 on each side, of equal size, in a dark patch.

Figs. 1-6.



*Achorutes tigridis*.

1. Olfactory hairs on antenna; 2 & 3. Post-antennal organ and anterior eyes;  
4. Apex of leg; 5, 5a. Apex of spring; 6. Tenaculum.

All figs.  $\times 720$ .

Post-antennal organ of 4 or 5 unequal papillæ. (Figs. 2 & 3.)

Legs each with one tenent hair. Claws curved, each with one very small inner tooth beyond the middle. Empodial appendage bristle-like, gradually tapering, without lamellæ, reaching to the tooth of the claw. (Fig. 4.)

Spring well-developed. Dens 2.75 times the length of the mucro, with

6 curved dorsal setæ and 4 or 5 dorsal rows of large papillæ. Mucro about .5 times the length of the claw, with narrow lamella ceasing suddenly before reaching the apex of the mucro. Apex of mucro with a peculiar dorsal tooth-like projection. (Fig. 5.)

Tenaculum with 4 barbs and no bristles. (Fig. 6.)

Anal spines small, slightly curved, on distinct papillæ which are contiguous at the base. Spine about equal in length to the height of the papilla, and about .5 times the length of the mucro.

Size from 1 to 1.2 mm.

*Locality.* Amara, on the Tigris (P. A. Buxton, 5. i. 1918).

Judging from the numbers collected, this species must be very plentiful in the district, and probably many live in association with each other, as is known to be the case with other species of the genus, vast swarms of individuals having been reported by various observers (Brown, 1921; Macnamara, 1919).

Serrated hairs seem to be somewhat exceptional in the members of the genus *Achorutes*, though the dorsal setæ of the common *A. armatus* Nic. occasionally exhibit the character. Ågren (1905, p. 5) described *A. serratus* from a single specimen from Lappland, having strongly serrated hairs. The present species differs from Ågren's in numerous important characters, notably in the structure of the sense organs on antenna IV, the post-antennal organ, and the claws. Numerous immature individuals, easily identified by the peculiar structure of the apex of the mucro, were present among humus from the Date Gardens at Amara (P. A. B.). Seen in certain positions, however, this character passes unnoticed, the mucro appearing as in fig. 5a.

#### ACHORUTES BUXTONI, sp. nov.

Colour yellowish-grey (in spirit), faintly and sparingly mottled with brownish pigment on the upper surface. Underside, limbs, and spring without dark colouring. Eye-patch dark. Skin finely granulated.

Hairs prominent, with especially long, strong, and distinctly curved ones near the posterior extremity of the abdomen.

Antennæ almost equal in length to the head. Segments III and IV indistinctly separated. The proportional lengths of the segments as 1:1:1.2:1.5. Antennal organ IV consisting of subapical papilla and 6 olfactory hairs.

Eyes 8 on each side, of equal size, the anterior pair being close together but not in contact.

Post-antennal organ consisting of 4 tubercles, the two outer ones being oval, the two inner ones more elongate and larger, in fairly close proximity to the anterior eyes. (Fig. 7.)

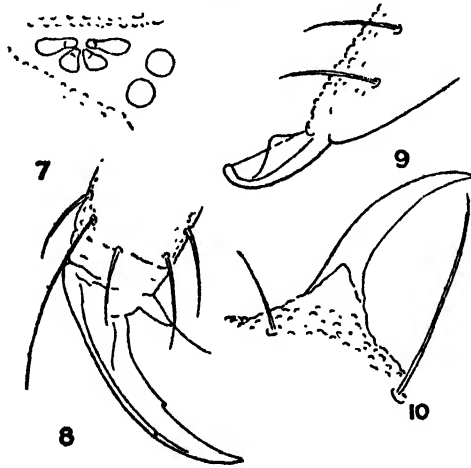
Legs without tenent hairs, but carrying a not specially prominent pointed spur hair. Claws strongly curved, with one small inner tooth beyond the

middle. Empodial appendage with a short, broad, triangular lamella, about  $\frac{1}{3}$  the length of the appendage, and an apical bristle reaching to  $\frac{1}{3}$  the length of the claw. (Fig. 8.)

Spring well-developed. Manubrium equal in length to the dens and mucro together. Dens broad and only slightly tapering, abruptly narrowing at the apex, with 6 or 7 dorsal setæ, with the dorsal papillæ not more prominent than the skin papillæ. Mucro much narrower than the dens, and about  $\frac{1}{2}$  the length of it, with strong ventral rib, upturned at the apex. Outer lamella broad and delicate, widest about the middle, and terminating before the apex of the mucro. Inner lamella narrower, and diminishing in width towards the base of the mucro. (Fig. 9.)

Tenaculum with 4 barbs.

FIGS. 7-10.



*Achorutes buxtoni*.

7. Post-antennal organ and anterior eyes; 8. Apex of leg; 9. Mucro and apex of dens; 10. Anal spine with its papilla.

Figs. 7-9  $\times 720$ ; fig. 10  $\times 450$ .

Anal spines very prominent, long and very strongly curved, rather longer than the claw and about equal to the length of the dens, on prominent papillæ, contiguous at the base. (Fig. 10.)

Size up to 1 mm.

*Locality.* In humus, gathered in Date Gardens, Amara, on the Tigris (P. A. Buxton, 1918).

In general appearance, owing to the long dorsal setæ, this species bears considerable superficial resemblance to *A. armatus* (Nic.), from which species and from *A. longispinus* (Tullb.) (Tullberg, 1876, p. 37) it differs, among other points, in the absence of the eversible antennal sacs and in the structure of the mucro. The exceptionally long and very strongly curved anal spines are noteworthy and characteristic.

Genus *ONYCHIURUS* Gervais.*ONYCHIURUS ARMATUS* (Tullb.).

*Lipura armata* Tullberg, Akad. afhandl. Upsala, 1869, p. 18; Öfv. Kongl. Vet.-Akad. Förhandl. Stockholm, 1871, p. 164.

*O. armatus* Börner, Zool. Anzeig. 1901, p. 698.

One damaged individual was referable to this species, which ranges across Europe and Siberia and occurs also in N. and S. America.

*Locality.* Kizil Robat (W. E. Evans, xii. 1918).

## Family ENTOMOBRYIDÆ Töm.

Genus *ISOTOMA* Bourl.

*Isotoma*, Bourlet, Mém. Soc. des Sci. de l'Agric. de Lille, 1839, p. 399.

„ Börner, *op. cit.* 1906, p. 171.

FIG. 11.



*Isotoma viridis*, var. *decorata*, var. nov. × 15.

*ISOTOMA VIRIDIS* Bourl.

Bourlet, *op. cit.* 1839, p. 401.

f. *PRINCIPALIS*.

*Locality.* Kizil Robat (W. E. Evans, xii. 1918).

var. *RIPARIA* (Nic.).

*Locality.* Kizil Robat (W. E. Evans, xii. 1918).

var. *DECORATA*, var. nov. (Fig. 11.)

Colour yellowish-brown, with reddish-brown interrupted markings.

A faint dorsal longitudinal interrupted line running through the body, with prominent spots at the anterior borders of the segments, which are especially prominent and peculiar shaped on the anterior abdominal segments. To each of these spots pass diagonal lines of spots, originating more anteriorly from a distinct spot on the strongly marked lateral line, the whole giving the impression, when viewed dorsally, of a series of V-shaped markings crossing the body. The flanks of the posterior segments, especially of abdomen IV and V, are more extensively darkened. Head similarly marked, with a transverse bar between the antennæ, and a posterior collar-mark on each side and a black eye-patch. Antennæ, legs, and spring pale.

In structural features the form agrees with European varieties of *I. viridis*, but the upper tooth of the claw is distinctly smaller and sometimes indistinct.

Size up to 4 mm.

*Locality.* Kizil Robat (W. E. Evans, xii. 1918).

#### Genus ISOTOMURUS Börn.

*Isotomurus* Börner, Sitzb. der Gesell. naturf. Freunde zu Berlin, 1903, p. 129.

##### ISOTOMURUS PALUSTRIS (Müll.).

*Podura palustris* Muller, Zool. Dan. Prodrum, 1776, p. 184.

*Isotoma palustris* Tullberg, Kongl. Sv. Vet.-Akad. Handl. Stockholm, 1872, p. 45.

*Isotomurus palustris* Börner, SB. Ges. naturf. Berlin, 1903, p. 171.

*Locality.* Kizil Robat (W. E. Evans, xii. 1918).

This is another species with extensive range, having been observed not only in Europe and Siberia, but in America, India (Imms, 1912, p. 93), and Java (Börner, 1906, p. 173).

#### Genus ENTOMOBRYA Rond., 1861.

*Degeeria* Nicolet, Nouv. Mém. Soc. Helv. Sci. Nat. 1842, p. 70.

*Entomobrya* Rondani, Dipterol. Ital. Prodr. v. (1861) p. 40 in notâ.

„ Börner, Mitth. Naturhist. Mus. Hamburg, 1906, p. 164.

##### ENTOMOBRYA OBSCURELLA, sp. nov.

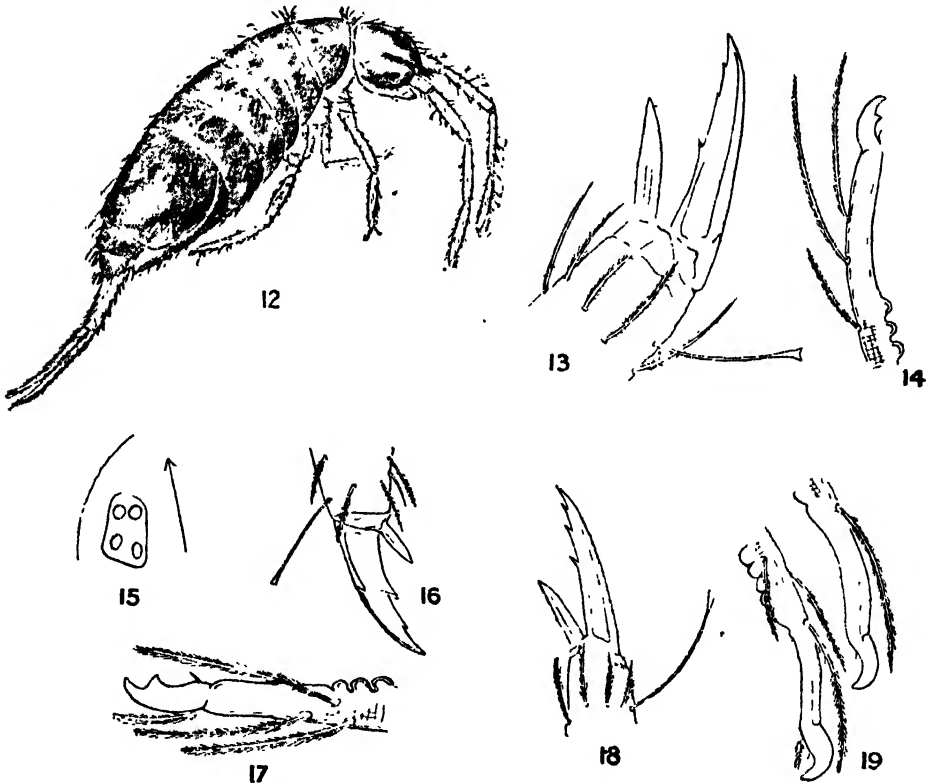
Colour dark purple, with indications of pale yellowish spots and areas. Head with the anterior margin, sides, and a median line extending half-way back, dark; the rest slightly paler and yellowish. Thorax dark, with a faint central line and small, narrow, elliptical spots arranged diagonally, yellowish. Abdomen dark, with small elliptical spots on the anterior margin of segment 1, the anterior margin and flanks of segment 3, an irregular double row on the anterior margin of segment 4, and two or three irregular patches on the flanks of segment 4, yellowish. The dorsal region of segment 4 in the posterior half, and the anterior margin of segment 5, yellowish.



Antennæ pale, with segment 1 and the upper side of segment 2 slightly darker. Legs pale, except for the basal segments. Spring pale. Some specimens are distinctly paler and show more indications of yellow colour. (Fig. 12.)

Body densely clothed with short, ciliated, clubbed hairs; a tuft of longer ones between the antennæ, on the anterior margins of the thoracic segments, and on the posterior segments of the abdomen.

FIGS. 12-19.



12-14. *Entomobrya obscura*, 13. Apex of leg; 14. Apex of spring.  
 15-17. *Sinella humicola*, 15. Eyes of the left side; 16. Apex of leg; 17. Apex of spring.  
 18-19. *Seira pallida*, 18. Apex of leg; 19. Apex of spring.

Fig. 12  $\times 30$ ; figs. 15-17  $\times 450$ ; figs. 13, 14, 18 & 19  $\times 720$ .

Eyes 8 on each side, on a black patch.

Antennæ about  $\frac{1}{2}$  the length of the body. The proportional lengths of the segments as 1 : 2 : 2 : 2.5.

Legs with an erect clubbed tenent hair. Claw with 3 inner teeth, one above the middle and two smaller ones nearer the apex, and 2 basal lateral teeth. Empodial appendage lanceolate, without teeth, nearly  $\frac{2}{3}$  the length of the claw. (Fig. 13.)

Spring long, about  $\frac{2}{3}$  the length of the antennæ. Dens about 1·3 times the length of the manubrium, tapering, dorsally crenulated, except in the apical region for a distance 2 or 3 times the length of the mucro, dorsally and ventrally with ciliated hairs. Mucro small, with apical and antepical teeth and a very small and indistinct basal spine. (Fig. 14.)

Tenaculum with 4 small barbs and 1 bristle.

Abdomen IV about 2·5 times abdomen III. Body-segments in the proportion 12 : 10 : 10 : 13 : 10 : 28 : 5 : 5.

Size up to 2 mm.

*Locality.* Under clods in a field near Kizil Robat, N.E. of Bagdad (W. E. Evans, xii. 1918).

In the disposition of the dark pigment the present species approaches somewhat *E. proxima* Folsom (Folsom, 1924, p. 507), from Sumatra, but differs in the peculiar character of the pale spots and in the absence of black hind borders to the body-segments, in addition to differences in the structure of the claws, mucro, and eyes.

#### ENTOMOBRYA LANUGINOSA Nic.

*Locality.* Ruz, under stones (W. E. Evans). In the Fig Gardens, Amara (P. A. Buxton).

These specimens, which were in a bad state of preservation, the single one from Amara being immature, are probably to be referred to this species on account of the absence of dark bands or other colouring and the presence of a dense covering of long, ciliated, clubbed hairs.

#### Genus SINELLA Brook.

*Sinella* Brook, Journ. Linn. Soc. Lond., Zool. 1882, p. 541.

„ Börner, SB. Ges. naturf. Berlin, 1903, p. 179.

„ Linnaniemi, Acta Soc. Scient. Fennicæ, 1912, p. 211.

As pointed out by Börner, and again by Linnaniemi, the most useful character for the separation of this genus from the very closely related *Entomobrya* is the presence in the former of a double row of naked or almost naked hairs on the inner face of the tibio-tarsi. Linnaniemi also notes the absence of a sensory club on the fourth segment of the antennæ.

#### SINELLA HUMICOLA, sp. nov.

Colour entirely white except for the dark eye-patch. Body hairy. Hairs clubbed and ciliated.

Eyes 4 on each side, in a single eye-patch. The two anterior eyes close together and the inner posterior rather larger and more elongate. (Fig. 15.)

Antennæ nearly half the length of the body. The proportional lengths of the segments as 3 : 5 : 5 : 9.

Legs each with 1 tenent hair weakly clubbed at the apex. Claws with paired lateral teeth, prominent basal teeth at about the middle of the claw, and 1 smaller apical tooth at about  $\frac{1}{4}$  the length of the claw from the apex (fig. 16). Hairs on the legs feathered, with a double row of almost naked hairs on the inner face of the tibio-tarsus.

Spring elongate, more than  $\frac{1}{3}$  and less than  $\frac{1}{2}$  the length of the body. Dens rather longer than the manubrium (as 5:4), tapering and dorsally crenulated in the basal three-quarters. Mucro very small, with apical and dorsal anteapical teeth and basal spine. (Fig. 17.)

Abdomen IV about 3.2 times abdomen III.

Size 0.75 mm.

*Locality.* In humus from the Date Gardens, Amara, on the Tigris (P. A. Buxton, 1918).

Two specimens only, not in very good condition, and possibly immature.

The structure of the mucro recalls *S. curviseta* Brook (Brook, 1882, p. 544) and *S. myrmecophila* Reut. (Reuter, 1886, p. 179), but differences are shown in the relatively smaller basal spine and especially in the number of eyes. In this last character the present species differs from previously described species, as shown in the following list:—

<i>S. hofti</i> Schöff. (Schöff., 1896, p. 192) ...	Eyes 0.
<i>S. montana</i> Imms (Imms, 1912, p. 101) ...	Eyes 0.
<i>S. curviseta</i> Brook, 1882, p. 544 . . . . .	Eyes 2 each side.
<i>S. humicola</i> (mihi) . . . . .	Eyes 4 each side.
<i>S. myrmecophila</i> (Reut.) ( <i>loc. cit.</i> ) . . . . .	Eyes 8 each side.

This genus appears, up to the present, to be restricted to the Northern Hemisphere.

#### Genus *SEIRA* Lubb.

*Seira* Lubbock, Trans. Linn. Soc. Lond. 1870, p. 279.

*Sira* Tullberg, Kongl. Sv. Vet.-Akad. Handl. Stockh. 1872, p. 41.

„ Schöff., Archiv f. Naturgesch. 1898, p. 411.

„ Schott, Arkiv f. Zool. 1917, p. 34.

This genus is closely related to *Lepidocyrtus*, and is to be distinguished from it by the dentes being unscaled ventrally, and the mesothorax, which in *Lepidocyrtus* generally projects more or less over the head, having the normal form, and in the structure of the scales.

#### *SEIRA* *PALLIDA*, sp. nov.

Colour yellowish. Eye-patch black, and a dark violet spot between the bases of the antennæ. Legs and spring pale. The three apical segments of the antennæ pale violet.

Body covered with scales; dorsally with a few scattered, short, feathered hairs; a tuft of long, ciliated, clubbed hairs between the bases of the antennæ and on the anterior margins of the thoracic segments and on the posterior abdominal segments.

Eyes 8 each side, on a dark patch.

Antennæ rather more than  $\frac{1}{3}$  the length of the body, the proportional lengths of the segments being as 4:7:8:10. The basal segments unscaled.

Legs with a clubbed tenent hair, the other hairs being feathered, those on the basal segments being very long. Claws elongate, narrow, with 3 prominent sharp-pointed inner teeth in the distal half. Claws of all legs alike. Empodial appendage lanceolate, without teeth, reaching to the first tooth of the claw. (Fig. 18.)

Spring equal in length to the antennæ. Dens rather longer than the munubrium, curved, tapering, thickly covered with feathered hairs, ventrally without scales. Mucro with a hook-like apical tooth and a basal spine. Mucro distinctly separated from the dens. (Fig. 19.)

Abdomen IV about five times abdomen III. Thorax not projecting over the head.

Size 1.7 mm.

*Locality.* Under a stone near Ruz, N.E. of Bagdad (W. E. Evans, xi. 1918).

This species appears to be rather closely related to *S. frigida* Imms (Imms, 1912, p. 97), occurring in India at an altitude of 12,300 feet. It differs, however, in the smaller size, the entire absence of colour, the larger and more prominent teeth to the claw, which are minute in *S. frigida*, and the much smaller basal spine to the mucro, which in the Indian species reaches the apex of the mucro.

### Genus PSEUDOSIRA Schött.

*Pseudosira* Schött, Bihang till K. Svensk. Vet.-Akad. Handl. 1893, p. 10.

„ Börner, Mitt. Nat. Mus. Hamb. xxiii. 1906, p. 164.

This genus is closely related to *Seira* and *Lepidocyrtus*, but may be distinguished, as pointed out by Imms (Imms, 1912, p. 101), by the ventrally-scaled dentes and hook-like mucro.

Shoebotham considers (Shoebotham, 1917, p. 431) that Lubbock's name *Seira* should be applied to this genus, and proposes *Willowsia* for the preceding genus in place of *Seira*. This procedure has been followed by Denis (Denis, 1924, p. 262), but it seems to me of rather doubtful necessity.

### PSEUDOSIRA EVANSII, sp. nov.

Colour dark yellow-brown with small paler spots; paler on the dorsal regions of the head and thorax and anterior abdominal segments, darker posteriorly and ventrally. The paler oval spots are most noticeable on the flanks of the abdominal segments and on the anterior margins of these segments. Legs dark brown, except for the pale tibio-tarsi. Antennal

segments I and II dark brown, segments III and IV paler. Manubrium brown, the remainder of the spring pale. (Fig. 20.)

Scales ovoid and striated.

Eyes 8 on each side, on a dark patch.

Antennae about  $\frac{1}{2}$  the length of the body. The relative lengths of the segments as 8:13:13:19. All the segments thickly haired, those on the basal segments specially long. Segments 1 and 2 and the base of 3 scaled. Last segments with an apical papilla.

Legs with a prominent strongly-clubbed tenent hair; the other hairs feathered, except one on the inner side of leg 3 immediately above the empodial appendage. Legs thickly scaled. Claws narrow and elongate, with 3 narrow, sharp-pointed inner teeth, the largest below the middle, the others in the apical quarter of the claw, and 2 lateral teeth nearly opposite the larger inner tooth. Empodial appendage  $\frac{2}{3}$  the length of the claw, lanceolate, tapering, with one very minute outer tooth one-third from the base. (Fig. 21.)

Spring rather less than the length of the antennae, reaching to the ventral tube, and about  $\frac{1}{2}$  the length of the body. Manubrium thickly scaled ventrally; dorsally with weakly-feathered curved hairs. Dens strongly crenulated dorsally, except for a short distance before the apex, equal to about three times the mucro. Dens tapering and curving dorsalwards; dorsally and ventrally with feathered hairs, and ventrally scaled. Dens slightly longer than the manubrium. Mucro very small and hook-like, without a basal spine, and not distinctly separated from the dens. (Fig. 22.)

Tenaculum with 4 barbs.

Abdomen IV about 3.5 times abdomen III.

Size up to 2.5 mm.

*Local'ty.* Under a clod in a field, Kizil Robat, N.E. of Bagdad (W. E. Evans, 19. xii. 1918).

In general features the present species recalls *P. domestica* (Nic.), the common European form, and *P. indra* Imms (1912, pp. 100-101), differing from them, however, in size, colour, and in several minor structural points.

I am pleased to associate this fine species with the name of its discoverer.

### Genus LEPIDOCYRTUS Bourl.

*Lepidocyrtus* Bourlet, *op. cit.* 1839, p. 391.

„ Börner, *op. cit.* 1906, p. 164.

„ Schött, *Arkiv f. Zool.* 1917, p. 33.

LEPIDOCYRTUS SIMULARIS, sp. nov.

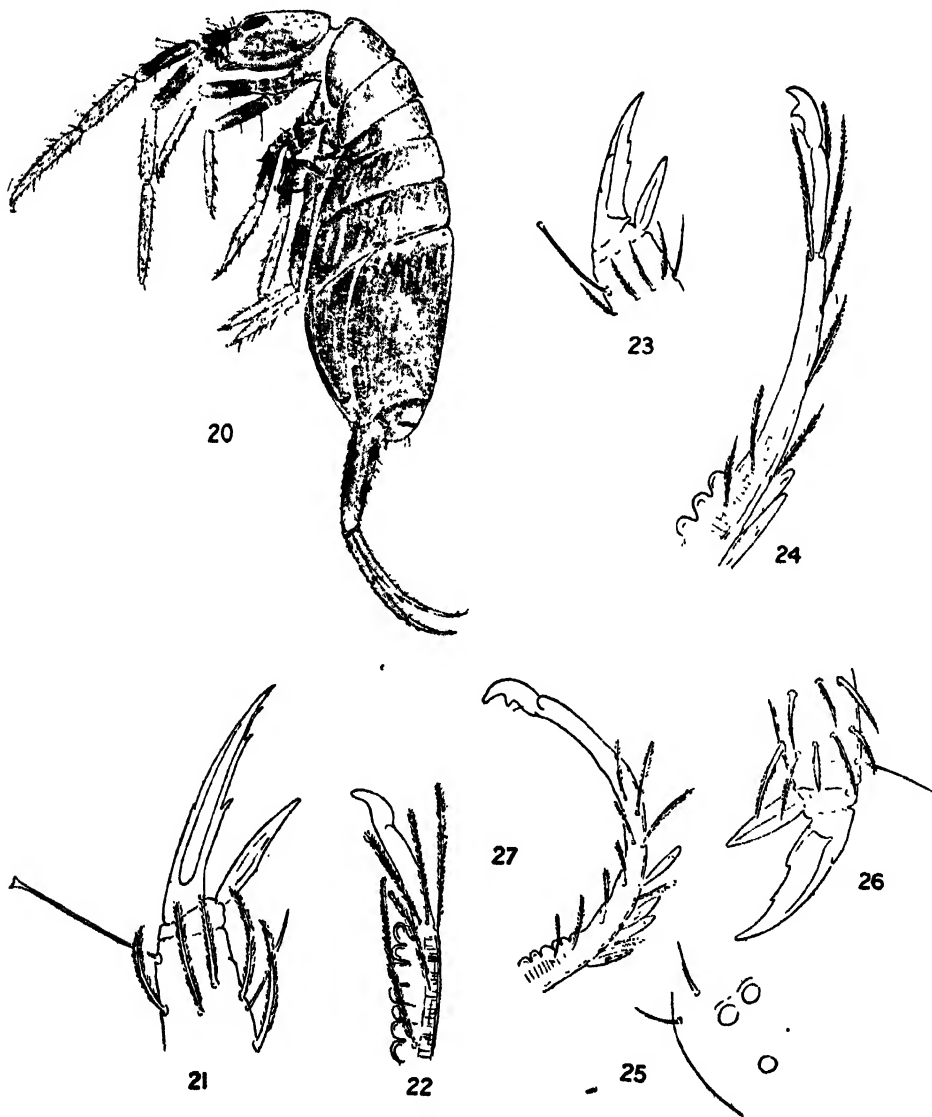
Colour pale violet (yellowish when rubbed), mottled with yellow. Antennae violet, legs pale violet, spring pale yellow, ventral side pale. Body darker towards the head.

Body thickly scaled.

Eyes 8 each side, on a dark patch.

Antennæ 1.75 times the length of the head. The proportional lengths of the segments as 2:3:3:5. The two basal segments and a portion of the third scaled.

FIGS. 20-27.



20-22. *Pseudosira evansii*, 21. Apex of leg; 22. Apex of spring.

23-24. *Lepidocyrtus similaris*, 23. Apex of leg; 24. Apex of spring.

25-27. *Heteromurus sexoculatus*, 25. Eyes of left side; 26. Apex of leg; 27. Apex of spring.

Fig. 20  $\times 30$ ; figs. 21-27  $\times 720$ .

Legs with one clubbed tenent hair, the other hairs feathered, except one on the inner side of leg 3. Claw with 2 small indistinct inner teeth, one at the middle and the other  $\frac{1}{2}$  from the apex of the claw. Empodial appendage lanceolate, untoothed, and about  $\frac{2}{3}$  the length of the claw. (Fig. 23.)

Spring long, reaching the ventral tube, slender, curving. Dens crenulated dorsally, except for a considerable distance before the apex, dorsally with feathered hairs and ventrally scaled (fig. 24). Mucro with apical and anteapical teeth and a basal spine.

Thorax not projecting over the head. Abdomen IV about 3 times abdomen III.

Size 1.5 mm.

*Locality.* Among debris on the margin of the Tigris, above Amara (W. E. Evans, 20. x. 1918), and under a stone near Ruz, N.E. of Bagdad (W. E. Evans, xi. 1918).

The present species differs from the European *L. cyaneus* Tull., which it resembles, in the body-colour (seen when the scales are removed), the relatively shorter fourth abdominal segment, and the relative lengths of manubrium and dens.

#### Genus *HETEROMURUS* Wank., 1861.

*Templetonia* Lubbock, Trans. Linn. Soc. Lond. 1862, p. 595.

„ Tullberg, Öfv. Kongl. Vet.-Akad. Förhandl. 1871, p. 149; Kongl. Sv. Vet.-Akad. Handl. 1872, p. 44.

#### *HETEROMURUS SEXOCULATUS*, sp. nov.

Colour uniform yellowish-brown, except for the dark eye-patch. Legs, spring, and antennæ pale.

Body covered with pale scales. Head between the bases of the antennæ, anterior margins of meso- and metathorax, with a tuft of ciliated clubbed hairs. Posterior segments of the abdomen with short ciliated hairs. Legs with short, thick, and minutely feathered hairs, two prominent, erect, weakly feathered hairs on the anterior face of the tibio-tarsi, and several longer unciliated bristles on the basal segments.

Eyes 3 each side, two anterior and one posterior, on a triangular dark patch. (Fig. 25.)

Antennæ 5-jointed, nearly  $\frac{1}{2}$  the length of the body. The relative lengths of the segments as 3 : 6 : 11 : 11 : 16. The basal segment weakly separated from the second. The three basal segments scaled, the terminal segment secondarily ringed.

Legs thickly scaled, with one long, pointed, slightly curved, unthickened spur hair. Claw with 2 inner teeth, one below the middle and a smaller one beyond, equally spaced. Empodial appendage without teeth, lanceolate, and about  $\frac{2}{3}$  the length of the claw. (Fig. 26.)

Spring about equal to the antennæ. Dens dorsally crenulated, except for nearly  $\frac{1}{2}$  of its length from the apex, dorsally with ciliated hairs, ventrally

scaled, elongate and tapering, and about 2·3 times the manubrium. Mucro with an apical and an anteapical tooth and a small basal spine. (Fig. 27.)

Mesothorax not projecting over the head.

Abdomen IV about 1·5 times abdomen III.

Size up to 2 mm.

*Locality.* Under clods in a field, Kizil Robot, N.E. of Bagdad (W. E. Evans, xii. 1918).

#### Genus ORCHESELLA Templ.

*Orchesella* Templeton, Trans. Ent. Soc. Lond. 1834, p. 93.

#### ORCHESELLA LINEATA, sp. nov.

Colour yellowish (in spirit), with blue-black or violet markings. Head with the eye-patches dark, a faint patch lateral to the mouth-parts, a dark transverse bar between the antennæ, and a fainter mark behind each eye, being the beginning of a marginal longitudinal line extending to the third abdominal segment. A very fine central longitudinal line extends through the thorax and the first two abdominal segments, and a more pronounced lateral line through the thorax and the abdominal segments, being interrupted in the fourth abdominal segment. Abdominal segment 3 with a broad transverse band, extending the width between the two lateral longitudinal lines, and partially interrupted in the median line. Abdomen IV with two transverse bands, a narrow one at the posterior margin, and a broader and fainter and generally much interrupted one anterior to the middle of the segment. Abdomen V and VI each with a posterior transverse band, interrupted in the middle of the segments. In addition, abdomen III and IV with ill-defined lateral patches.

Thus there are 5 longitudinal lines extending back more or less completely to abdomen III, a broad dark transverse band on abdomen III, and narrow ones on the posterior margins of abdomen IV, V, and VI, interrupted in the middle of the last two segments. (Fig. 28.)

Some specimens are paler, and the anterior band and lateral flecks on abdomen IV are indistinct.

Antennæ with the first and third segments dark, the second sometimes pale violet in the basal two-thirds, the fifth with slightly marked rings near the base and apex, and the sixth faintly darkened towards the apex.

Legs pale, with dark patches on the basal segments and a bluish streak on the outer side of the femora of legs 2 and 3, and sometimes faintly shown on leg 1.

Spring entirely pale.

Antennæ rather more than  $\frac{1}{2}$  the length of the body. The proportional lengths of the segments as 1 : 3 : 1 : 5·5 : 8·5 : 10.

Legs with a prominent clubbed tenent hair. Claw with one inner tooth at the middle and two small ones in the apical half, and two lateral basal teeth.



Empodial appendage lanceolate, scarcely  $\frac{2}{3}$  the length of the claw, with one very small inner tooth rather beyond the middle in leg 3. Claw about 2.75 times the length of the mucro.

Spring long, rather longer than the antennæ. Mucro with apical and anteapical teeth and a basal spine. Dens nearly 1.3 times the manubrium.

Body densely clothed with thick ciliated hairs.

Size 2 mm.

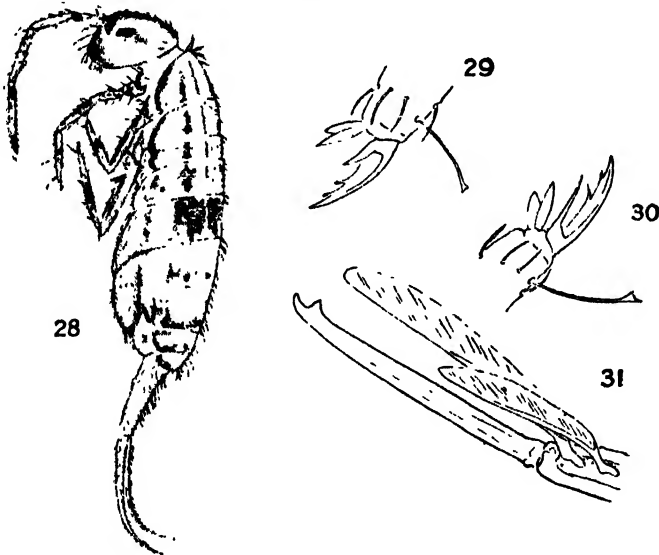
*Locality.* In debris on the margin of the Tigris, below Amara (W. E. Evans, 21. x. 1918).

### Genus CYPHODERUS (Nic.).

*Cyphodeirus* Nicolet, Nouv. Mém. Soc. Helv. Sci. Nat. 1842, p. 63.

*Cyphoderus* Tullberg, Öfv. Kongl. Vet.-Akad. Förhandl. 1871, p. 150.

FIGS. 28-31.



28. *Orchesella lineata*,  $\times 30$ .

29-31. *Cyphoderus amaranus*, 29. Apex of leg 1 or 2; 30. Apex of leg 3; 31. Apex of spring.  
Figs. 29-31  $\times 720$ .

### CYPHODERUS AMARANUS, sp. nov.

Colour entirely white. Eyes absent. Body scaled.

Antennæ about 1.5 times the length of the head, rather more than  $\frac{1}{3}$  the length of the body. The antennal segments in the proportion 3 : 6 : 4 : 8.

Abdomen IV 3.5 times abdomen III.

Legs with one tenent hair, distally clubbed (spathulate), and about equal in length to the claw. Claws of leg 3 different from those of legs 1 and 2. Claws of legs 1 and 2 (fig. 29) with a pair of prominent basal teeth reaching half-way up the claw, and two pointed inner teeth in the distal half.

Empodial appendage about  $\frac{3}{4}$  the length of the claw, with a prominent broad outer tooth. Claw of leg 3 (fig. 30) with the basal teeth more elongate, and reaching about  $\frac{3}{4}$  up the claw, with two inner teeth as in the other legs. Empodial appendage with a much broader outer tooth.

Spring rather longer than the antennæ and less than half the body. Manubrium scaled ventrally. Dens dorsally with feathered hairs, and two rows of ribbed, dorsal scales, 5 inner and 6 outer, of which the distal inner scale reaches the dorsal tooth of the mucro, and the distal outer scale reaches to about half the length of the mucro. Dens rather more than twice (about 2.3) the length of the mucro. Mucro straight, with hooked apical and one dorsal anteapical tooth. (Fig. 31.)

Size up to 1.7 mm.

*Locality.* In an old grain store, Amara, on Tigris (W. E. Evans, 28. ix. 1918).

Members of this genus are usually associated either with ants or with termites (Brown, 1920), though this is not always the case (Carpenter, 1913). It is quite possible the present species agrees in this respect, though we have no record to that effect.

*C. amaranus* differs considerably in structure from all the species described from Egypt by Wahlgren (Wahlgren, 1906), and appears to be most nearly allied to *C. assimilis* Born. (Börner, 1913, p. 277) and *C. simulans* Imms (Imms, 1912, p. 115), differing essentially in the dissimilarity of the claws of legs 1 and 2, and of leg 3, and in the relatively longer inner distal scale of the dens.

### Sub-order SYMPHYPLEONA Börn.

#### Family SMINTHURIDÆ Lubbock.

#### Genus SMINTHURUS Latreille.

*Smynturus* Latreille, Hist. Nat. 1804.

*Sminthurus* Tullberg, Kongl. Sv. Vet.-Akad. Handl. 1872, p. 29.

„ Börner, Mitth. Naturh. Mus. Hamburg, 1906, p. 183.

#### SMINTHURUS VIRIDUS (L.) Lubbock.

*Podura viridis* Linnæus, Syst. Nat. 1758, p. 608.

*Smynturus viridis* Lubbock, Monograph, 1873, p. 100.

*Locality.* Kizil Robat (W. E. Evans, xii. 1918).

The specimens belong apparently to var. *nigromaculata* Tallb., having (in spirit) a yellow-brown ground-colour, mottled with black pigment, especially on the flanks. Börner describes (Börner, 1901, p. 115) the anal appendage of this species as being nearly equal to the mucro; Linnaniemi (1912, p. 313) gives it as  $\frac{3}{4}$  of the mucro. In all the specimens which I have examined, whether in the present collection or in British gatherings, it was nearer  $\frac{1}{2}$  the mucro.

*Distributional Note.*

Owing to the smallness of the collections here described, no very general conclusions as to the faunal relationship can be drawn. If it is allowable to regard the species obtained as typical of the country, it is obvious that so far as regards the Collembola, Mesopotamia resembles the Palaearctic region. As mentioned above, all the genera represented occur commonly in Europe, some being probably cosmopolitan, and none of those which one regards as more peculiar to the East or to the more tropical countries (Carpenter, 1916; Imms, 1912, etc.) occur. Some of the species are identical with those found in Europe (and even in Britain), while one or two of those described as new show some approach to Oriental forms.

It is curious that the only representative of the highest sub-order, the Symphypleona, should be the common *Sminthurus viridis*.

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Biscayan Plankton collected during a Cruise of H.M.S. 'Research,' 1900.—Part XIV. The Copepoda. By G. P. FARRAN. (Communicated by G. HERBERT FOWLER, Ph.D., F.L.S.)\*

(PLATES 5-10 and 2 Text-figures.)

[Read 18th March, 1920.]

PAPERS have appeared from time to time in the 'Transactions of the Linnean Society' (ser. ii. Zool. vol. x.) dealing with the various groups taken in the collections made by Dr. G. H. Fowler on board H.M.S. 'Research' in the Bay of Biscay in 1900. Reference should be made in particular to the report on the Ostracoda by Dr. Fowler (1909), in which the vertical distribution and diurnal movements of that group have been worked out in detail.

In the present paper, the appearance of which has been delayed by various causes, an attempt has been made to treat the Copepoda as far as possible on similar lines.

It may be mentioned that this paper was written before the publication of Fascicule lxi. of the Monaco reports, containing figures of the Copepoda described or recorded by Prof. G. O. Sars in the earlier Bulletins of the Monaco Museum, the necessary alterations consequent on its appearance being subsequently inserted.

The 'Research' collections were made from July 7 to July 25, 1900, approximately in the centre of the Bay of Biscay. The stations, which on a small-scale map of Europe appear to be all on the same spot, are actually scattered over an area bounded on N. and S. by  $47^{\circ} 29' \text{ N.}$  and  $46^{\circ} 43' \text{ N.}$ , and on E. and W. by  $8^{\circ} 18' \text{ W.}$  and  $7^{\circ} 15' \text{ W.}$ , and lie mainly along a diagonal line, about 65 miles in length, from the N.W. to the S.E. corner. The soundings taken lay between 1219 and 2341 fathoms. The positions lie just outside the Continental slope and across the path of the Atlantic drift, and it seems possible that the physical conditions and the relation to ocean currents may have varied sufficiently within the area investigated to make a recognisable difference in the copepod fauna on the several stations, although no differences could definitely be attributed to such a cause.

The Copepoda taken by the 'Research' fall, according to the method of collection, into two groups, which require to be dealt with differently.

The Epipelunkton collections, *i.e.* those down to 100 fathoms and also a few hauls between 100 and 350 fathoms, were made with horizontal nets, hauled to the surface without closing, and cannot be treated quantitatively, as only a sample of the Copepoda from each gathering was examined. The percentage of each species in the different gatherings has been calculated,

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and has given a good deal of information as to their actual movements and relative abundance.

These hauls were of long duration, one hour or more, and the catch made whilst the net was being hauled to the surface is probably so small proportionately that it does not materially affect the total.

The deep-water hauls, with the exception of the few mentioned above, were made with closing nets hauled vertically, and all the copepods in each gathering have been examined and counted.

In computing the average number of specimens per haul of the various species at different depths, the hauls in which the species did not occur have been taken into account.

In all the counts given in this paper all specimens have been included which could be identified with reasonable certainty whether mature or immature, or living or dead when caught. In the vertical hauls from deep water the proportion of dead to living increases with the depth, but it is impossible in practice to make a satisfactory line of division between them, as all stages of disintegration, from perfect specimens to broken and crushed fragments of carapace, may be met with. In the count, such fragments have been omitted, but anything which could be called a specimen, even though crushed or with broken appendages, has been enumerated.

To give a true picture of the conditions in deep water, it is necessary to give some indication of the falling-off in the proportion of living individuals with increase in depth. At 750-500 fathoms the numbers of living or fresh specimens and those certainly dead when taken are about equal. At 1000-750 fathoms the following figures were noted: (31*d*) live 216, dead 235; (32*k*) live 168, dead 555. At 1250-1000 fathoms there were: (27*b*) live 32, dead 224; (31*c*) live 72, dead 66. At 1500-1250: (30*i*) live 23, dead 207. At 2000-1500: (26*b*) live 13, dead 10. The probabilities of errors in discrimination are always in favour of the living specimens, and the numbers of specimens which could be said with certainty to have been alive in the four last-mentioned townetings are (27*b*) 18, (31*c*) 18, (30*i*) 12, (26*b*) 9.

#### *Epiplankton Hauls.*

A series of hauls both day and night were made at the surface, 25, 50, 75, and 100 fathoms. The nets used were of silk with 60 or 65 meshes to the linear inch and, at the surface only, 180 meshes to the linear inch. They are referred to in the paper as Nets 60, 65, and 180. The actual nets used are not at the present time available, but the size of the meshes, as found by measuring samples of standard silk with the given number of meshes to the inch, is, for net 60, .31 mm. square and, for net 65, .24 mm. square. Net 180 has meshes of about .07-.08 mm. square. The trade numbers of standard silk corresponding to the three nets are respectively 3, 5, and 20. Grit gauze and the heavier makes of bolting silk, in which the strands of silk are thicker, give a slightly smaller mesh.

Net 180 clearly retains a good deal of material which would have passed through the meshes of nets 60 and 65; but at first sight it might be imagined, and I commenced to deal with the collection under the belief, that the catches of nets 60 and 65 might be treated together as regards comparative results. In practice, however, it appeared that the difference in mesh was an important one, and that at least two plentiful species were retained by the finer net, while passing readily through the coarser.

These two species are *Paracalanus parvus* and a small form of *Clausocalanus* to which for convenience I have given the name of *C. pergens*, although it is possible that it may be merely a small race of *C. arcuicornis*.

The average proportions of *C. pergens* in the catches of nets 60 and 65 at various depths are as follows:—

	NET 60.		NET 65.	
Surface .....	9 hauls	·32 per cent.	4 hauls	10·7 per cent
25 fms. ....	4 "	·78 "	8 "	11·6 "
50 " .....	11 "	1·14 "	1 "	8·9 "
75 " .....	3 "	·29 "	8 "	11·8 "
100 " .....	20 "	·68 "	1 "	19·7 "

These figures show that the difference was not due to one net being used at depths or times at which the species was most plentiful, for both nets were used at all hours of day and night. Taking an average over all collections, the catch of *C. pergens* for net 60 amounted to ·64 per cent. and for net 65 to 11·9 per cent. of the total catch.

For *Paracalanus parvus* the corresponding figures are:—

	NET 60.		NET 65.	
Surface .....	9 hauls	·19 per cent.	4 hauls	18·1 per cent.
25 fms. ....	4 "	·78 "	8 "	9·6 "
50 " .....	11 "	·38 "	1 "	3·2 "
75 " .....	3 "	·02 "	8 "	3·1 "
100 " .....	Normally absent.			

Over all collections the average percentage of *P. parvus* for net 60 is ·19 and for net 65 8·5.

It follows that if 1190 specimens of *C. pergens* were taken by net 65, only 64, or 5·9 per cent., would have been taken by net 60, and 1126, or 94·1 per cent., would have passed through the meshes; and in the case of *P. parvus*, out of 850 specimens taken by net 65, only 19, or 2·2 per cent., would have been retained by net 60, and 831, or 97·8 per cent., would have escaped.

It is evident that the critical size of mesh for *C. pergens* is about ·3 mm. square, for the average length of the species is ·9 mm. and the diameter of the cephalothorax ·3 mm.; consequently an opening of greater than ·3 mm. will allow of its passage head foremost with the appendages closely pressed against the body. *P. parvus* is more variable in size, but on an average slightly smaller and more slender, and we find accordingly that an even

smaller proportion of specimens than in the case of *C. pergens* are retained by a mesh of .31 mm.

All the species of *Oithona*, viz. *O. similis*, *O. atlantica*, and *O. setigera*, probably can pass through both nets, but the average figures of 4.4 per cent. for the catch of net 60 and 14.96 per cent. for net 65 for all species collectively show that the mesh in this case, too, does make a difference.

In comparing the catches at various depths with nets 60 and 65 in the following pages, net 60 has been taken as a standard, and the catch of net 65 has in the case of *Clausocalanus pergens* been reduced by 94.1 per cent., of *Paracalanus parvus* by 97.8 per cent., and of *Oithona* spp. by 71 per cent., and the percentages of the other species present are calculated on the diminished total.

It is probable that other less abundant small species were also taken in greater numbers by net 65 than by net 60; some of these cases are referred to while dealing with the species in question, but it has not been thought necessary to take them into account when estimating the percentages of the other species.

The same general conclusions as regards the distribution of species in the epiplankton would, no doubt, have been arrived at if the correction dealt with above had been neglected, but they would have been open to the objection that a known source of error of unknown extent had been passed over.

It is well known that the meshes of a tow-net tend to become smaller with use, and it follows from the above observations that its catching power, while diminished as a whole, owing to the decreased flow of water through it, will be increased as regards those species which narrowly escape capture when it is new.

#### *Day and Night Distribution of the Epiplankton.*

The hauls made above 100 fathoms have been arbitrarily divided into day and night hauls, the night hauls being those at the surface, 25 fathoms, and 50 fathoms taken between 7.30 P.M. and 4.15 A.M., those at 75 fathoms between 7.0 P.M. and 4.15 A.M., and those at 100 fathoms between 7.0 P.M. and 4.30 A.M.

Species at the surface, taken with nets 60 and 65, which show a marked increase by night are:—

	Day percentage.	Night percentage.
<i>Metridia lucens</i> .....	3.0	9.4
<i>Pleuromamma robustum</i> .....	0	3.2
<i>Pleuromamma gracile</i> .....	.01	4.0
<i>Acartia Clausi</i> .....	6.9	12.9
<i>Oithona similis</i> .....	1.1	7.6
Day hauls 9.		Night hauls 4.



With net 180 there is a slight difference, the species being :—

	Day percentage.	Night percentage.
<i>Metridia lucens</i> .....	0	3·3
<i>Pleuromamma robustum</i> .....	0	·6
<i>Pleuromamma gracile</i> .....	0	2·8
<i>Acartia Clausi</i> .....	8·5	16·0
<i>Paracalanus parvus</i> .....	6·2	10·3
Day hauls 6.	Night hauls 3.	

The proportions of *Oithona similis* are the reverse of those found with nets 60 and 65, viz. 46 per cent. by day and 13·5 per cent. by night.

At 25 fathoms the species are :—

	Day percentage.	Night percentage.
<i>Undeuchæta minor</i> .....	·03	·87
<i>Euchirella curticauda</i> .....	0	·48
<i>Scolecithrix dentata</i> .....	0	·54
<i>Metridia lucens</i> .....	·82	10·6
<i>Pleuromamma robustum</i> .. ...	·18	5·9
<i>Pleuromamma gracile</i> .....	·31	9·4
Day hauls 6.	Night hauls 6.	

At 50 fathoms the species are the same as at 25.

	Day percentage.	Night percentage.
<i>Undeuchæta minor</i> .....	0	5·96
<i>Euchirella curticauda</i> .....	0	1·14
<i>Scolecithrix dentata</i> .....	·04	1·9
<i>Metridia lucens</i> .....	·2	18·3
<i>Pleuromamma robustum</i> .....	·23	16·6
<i>Pleuromamma gracile</i> .....	·14	15·2
Day hauls 8.	Night hauls 5.	

At 75 fathoms, although the day hauls are only three in number, the results are the same.

	Day percentage.	Night percentage.
<i>Undeuchæta minor</i> .....	·02	1·56
<i>Euchirella curticauda</i> .....	·13	·67
<i>Scolecithrix dentata</i> .....	·08	·88
<i>Metridia lucens</i> .....	3·3	13·1
<i>Pleuromamma robustum</i> .....	·53	8·6
<i>Pleuromamma gracile</i> ... ..	·43	7·7
Day hauls 3.	Night hauls 8.	

At 100 fathoms two species disappear from the lists, as they do not show any significant difference between day and night distribution. The percentages for the others, including two fresh species, *Scolecithrix echinata*,

which seems to show a true nocturnal rise, and *Centropages typicus*, whose increased percentage at night is probably due to chance "patchiness," are :—

	Day percentage.	Night percentage.
<i>Undeucheta minor</i> .....	·04	3·7
<i>Scolecithrix echinata</i> .....	0	·29
<i>Metridia lucens</i> .....	5·7	23·4
<i>Pleuromamma robusta</i> .....	·56	17·2
<i>Pleuromamma gracilis</i> .....	·79	17·0
<i>Centropages typicus</i> .....	2·2	5·8
Day hauls 12.		Night hauls 9.

It seems clear that, during the period of the 'Research' observations, the copepod population from the surface to 100 fathoms, as sampled by nets 60 and 65, was approximately doubled during the night by an upward migration consisting mainly of *Metridia lucens*, *Pleuromamma robusta*, *P. gracilis*, and, from 50 fathoms downwards, *Undeucheta minor*. Other species which join in the migration, as may be seen by reference to the tables of distribution below, are *Eucheta acuta*, *Eucheta gracilis*, *Euchirella curticauda*, *Chirundina Streetsi*, *Undeucheta major*, *Scolecithrix dentata*, *Scolecithrix echinata*, *Scolecithrix ovata*, *Pleuromamma abdominalis*, *P. xiphias*, and probably others whose numbers are too small to show the phenomenon clearly. *Acartia Clausi* seems to increase at the surface during the night, with a corresponding decrease at 25 and 50 fathoms, while its distribution at 75 and 100 fathoms is not altered materially.

One result of this migration is that species whose numbers are actually unaltered by night appear as forming a much smaller percentage of the haul, and the movements of species which descend at night, if there are any such, are obscured.

#### Deep-water Hauls.

(a) Horizontal hauls with open nets, which were hauled to the surface without being closed, were made, by day only, with nets of 60, 45, and 36 meshes to the inch at the following depths :—150 fathoms (net 60), 200 fathoms (net 45), 250 fathoms (nets 60 and 36), 300 fathoms (net 45), and 350 fathoms (net 36).

Forty-five meshes to the inch corresponds to Standard silk No. 1 with openings of ca. ·36 mm. square ; thirty-six meshes to the inch to Standard silk No. 0 with openings of ca. ·54 mm. square.

As the number of hauls were not sufficient to allow of any comparison of their catching powers, the proportion of species composing the hauls has been given without correction, and it must be emphasized that the resulting figures cannot safely be compared directly with those of the epiplankton nets.

(b) Vertical hauls with nets 36 and 45 were made at various depths between 2000 and 50 fathoms. The whole catch of these hauls has been examined and counted, and the results are given under each species as the average number of specimens present in a vertical haul of 100 fathoms.

*Numbers of Species and Specimens at various Depths.*

The following is a tabular summary of the numbers of species and specimens in the hauls at the various horizons :—

## (a) Horizontal Hauls.

Depth in ms. ....	MESH 180.	MESH 60 and 65.				
		0	25	50	75	100
Total number of species. . . .	31	42	49	56	67	75
Total in day hauls . . . . .	14	34	37	32	44	63
Total in night hauls . . . . .	28	33	47	51	63	63
Average number of species per haul	by day ..	7	14	19	17	28
	by night.	17	17	27	33	38
Depth in fms. ....	150	200	250	300	350	
Total number of species. . . . .	38	47	57	56	79	
Average no. of species per haul.	38	30*	46	56	79	

## (b) Vertical Hauls.

Depth in fms. ....	150	150	200	250	300	400	500	750	1000	1250	1500	2000
	to	to	to	to	to	to	to	to	to	to	to	to
	50	100	100	150	200	300	400	500	750	1000	1250	1500
Total no. of species ..	20	17	47	43	44	50	57	66	65	22	14	11
Number of hauls ....	1	1	6	3	3	3	3	4	3	2	1	1
Average per haul. . . .	20	17	25	30	23	31	32	39	36	18	14	11
Average specimens per 100 fms. of haul	515	164	425	781	522	373	296	232	245	78	88	46

Out of the 150 species of Copepoda in the collection, a number of little-known forms were met with, but only one genus, *Bathydia*, and fourteen species are described as new, viz. :—

*Calocalanus contractus.*

*Calocalanus tenuis.*

*Calocalanus pergens.*

*Clausocalanus paululus.*

*Scolecithrix curta.*

*Scolecithrix Fowleri.*

*Scolecithrix falcifer.*

*Scolecithrix valens.*

*Scolecithrix laminata.*

*Lucicutia gemina.*

*Haloptilus buliceps.*

*Euaugaptilus humilis.*

*Ratanium atlantica.*

*Bathydia remota.*

In the tabular lists of species captured at the different stations, given at the end of the paper, only the vertical hauls made with closing nets have been included. The data for the horizontal net hauls, which are of considerable bulk, have been deposited along with the collections themselves in the Zoological Department of the British Museum. As these data do not give the actual number of specimens, but only the percentage composition, and as they have been summarised under the headings of the separate species, it has not been thought necessary to print them in detail.

\* Sample from one haul too small to be fully representative.

# CALANUS FINMARCHICUS (Gunner).

## Distribution.—

Depth.	By day in				By night in			
0 fms.	8 out of 9 hauls, with 5.2			Per	4 out of 4 hauls, with 1.9			Per
25	6	6	6.3	cent.	5	6	.6	cent.
50	7	7	7.9	of	5	5	2.7	of
75	3	3	4.1	aver.	8	8	.6	aver.
100	11	12	1.2	haul.	9	9	.9	haul.

At 150 fms.	in 1 out of 1 haul, with 1.2			} Per cent. of average haul.
200	1	2	1.5	
250	2	2	7.2	
300	1	1	4.5	
350	1	1	4.2	

Between	150—	50 fms.	in 0 out of 1 haul, with 0		} Average specimens per 100-fathom haul. (1 specimen). (1 „ ).
	200—	100	2	6	
	250—	150	2	3	
	300—	200	3	3	
	400—	300	3	3	
	500—	400	3	3	
	750—	500	4	4	
	1000—	750	3	3	
	1250—	1000	2	2	
	1500—	1250	1	1	
	2000—	1500	1	1	

The wide variation in the numbers present in individual hauls in the epiplankton makes the percentages given above somewhat doubtful. Thus by day at the surface it varied from 0 to 15 per cent., at 25 fathoms from 2.5 to 19 per cent., and at 50 fathoms from 1.1 to 22.4 per cent. At 75 and 100 fathoms the occurrences are more uniform, being 2.9–5.5 and 0–4.8 per cent. The figures for the horizontal hauls between 150 and 350 fathoms are also not very reliable, being based on one or two hauls at each depth.

Vertical hauls, all taken by day, show a maximum between 300 and 1000 fathoms, or, perhaps more correctly, a deficiency between 75 and 200 fathoms, and in this they are supported by both series of horizontal hauls. Making allowance for a doubling of the population by night above 100 fathoms, there still remains an excess by day in the epiplankton, which may be an indication of a true upward movement, and may explain the apparent deficiency between 75 and 200 fathoms. A diurnal oscillation between the surface and 200 fathoms which does not affect specimens at lower depths does not in itself appear improbable, and the occurrence of shoals of *C. finmarchicus* at the surface by day in shallow water has been noticed, though the circumstances which give rise to it are not known.

Esterly (1911 *b*), making his observations at San Diego on stage V and adults only, has, on the contrary, found evidence for a well-marked maximum at the surface between 8 P.M. and midnight and at 10–15 fathoms at midnight.

Other maxima at various depths at other hours of day and night are indicated in his paper, but do not seem to form part of a uniform movement, and his general conclusion that there is a movement away from the upper waters during the day and away from the lower waters during the night does not seem to be definitely proved by the data which he gives, unless perhaps as regards the upper 50 fathoms or less.

The 'Research' figures include all stages taken collectively, and possibly this fact has obscured evidence which might have supported Esterly's theory of migration. The number of specimens available is, however, too few to make it profitable to consider them in detail. The following table shows the proportion per cent. of each stage in most of the samples in which 30 specimens or more were present:—

Station.	Depth.	Time.	Mesh of Net.	♂.	♀.	V.	IV.	III.	II.	I.	No. of specimens in sample.
23 d. . . .	0 fms.	3.30 P.M.-4.20 P.M.	60	--	—	15	38	44	3	—	39
23 e. . . .	0 "	4.40 P.M.-6.0 P.M.	60	—	—	21	43	36	—	—	33
24 i. . . .	0 "	12.15 A.M.-1.15 A.M.	60	8	16	35	22	18	—	—	51
25 l. . . .	0 "	2.0 A.M.-3.0 A. .	65	—	6	44	27	10	12	2	126
30 b. . . .	25 "	8.15 A.M.-9.15 A.M.	60	—	2	27	55	15	1	—	100
26 a. . . .	25 "	9.0 A.M.-10.0 A.M.	60	8	10	53	16	13	—	—	144
30 d. . . .	50 "	9.45 A.M.-10.30 A.M.	60	1	1	55	32	8	1	—	71
21 g. . . .	50 "	4.0 P.M.-4.30 P.M.	60	4	13	55	29	—	—	—	56
25 e. . . .	50 "	4.0 P.M.-5.0 P.M.	60	5	3	31	26	35	—	—	62
30 e. . . .	50 "	10.30 P.M.-11.30 P.M.	60	—	9	—	68	23	—	—	44
31 b. . . .	50 "	11.30 P.M.-12.30 A.M.	60	3	12	52	33	—	—	—	100
21 h. . . .	100 "	6.0 P.M.-6.30 P.M.	60	3	10	66	24	—	—	—	38

With (1915) has summed up the conclusion derived from his examination of material from the extreme North Atlantic, which, he says, was not well adapted for solving this question, as follows:—"All stages inhabit the surface layer in the night in some regions and at some seasons in which only the youngest copepodites or the larvæ are frequent during the day."

Length, ♀, 2.75-3.1 mm.; ♂, 2.96-3.3 mm.

#### CALANUS TENUICORNIS Dana.

##### *Distribution.*—

Depth.	By day in			By night in		
0 fms.	5 out of 9 hauls,	with 3.6	} Per cent. of average haul.	2 out of 4 hauls,	with 2.8	} Per cent. of average haul.
25	5	6		4	6	
50	6	7		5	5	
75	3	3		8	8	
100	12	12		9	9	

At 150 fms. in 1 out of 1 haul, with 2.8	} Per cent. of average haul.
200 1 2 1.0	
250 2 2 2.6	
300 1 1 .6	
350 1 1 3.2	

Between 150- 50 fms. in 1 out of 1 haul, with 12					
200-100	3	6	2·2	Average specimens per 100-fathom haul.	
250-150	1	3	·3		
500-200	0	9	0		
750-500	1	4	·2		
1000-750	0	3	0		
below 1000	0	4	0		

The lower limit for this species seems to be at about 200 fathoms, with a maximum at about 100 fathoms. It is true that it was taken in the horizontal nets fished at 350 fathoms, but the captures were probably made while the nets were being hauled. It sometimes occurs in shoals, one such shoal, extending in depth from 50 to 100 fathoms, having apparently been encountered on Station 30, worked during the day, where the percentages at 50, 75, and 100 fathoms were respectively 11·2, 34·0, and 42·8. If this station be omitted, the day percentages at 50, 75, and 100 fathoms are reduced to 5·3, 5·1, and 15·7.

By day *C. tenuicornis* is the most abundant species at 100 fathoms, and by night at the same depth it comes next in abundance to the negatively heliotropic species *Metridia lucens*, *Pleuromamma gracilis*, and *P. robusta*.

A count of the proportional numbers of the various stages present in some of the largest hauls gave the following figures:—

Station.	Depth.	Time.	Mesh of Net.	Percentage of stages.					
				♂.	♀.	V.	IV.	III.	II.
34c ....	75	3.0 - 4.0 A.M.	65	—	29	24	33	11	3
34d ....	100	3.0 - 4.0 A.M.	60	—	47	49	4	—	—
32o ....	75	12.0 - 1.15 A.M.	65	3	23	18	13	13	30
32n ....	100	10.30-11.30 P.M.	60	10	45	33	10	2	—
30d ....	50	9.45-10.30 A.M.	60	5	44	35	15	1	—
30l ....	50	10.30-11.30 P.M.	60	3	56	38	3	—	—
30g ....	100	1.0 - 2.0 P.M.	60	10	38	42	10	—	—
21n ....	100	6.0 - 6.30 P.M.	60	3	35	53	9	—	—

The large proportion of stages II and III in the catches of net 65 is evident, but there seems to be no connection between the percentages and the depth or time of day.

A comparison between the day and night collections in the epiplankton does not give any evidence for diurnal vertical movements.

Length, ♀, 2·12-2·18 mm.

#### CALANUS MINOR (Claus).

##### Distribution.—

25 fms. (35w) 1 ♂ 1 ♀, (34a) 1 ♀.

75 fms. (35e) 1 ♂.

100 fms. (32d) 1 ♀.

A Mediterranean and Atlantic species, probably here at the northern limit of its range. Though it was only taken in the epiplankton, we cannot

infer that it was exclusively an epiplanktonic form, as the epiplankton hauls were much more numerous and collected a much larger quantity of material than those at greater depths.

Length, ♂, 1.98–2.0 mm. ; ♀, 1.98–2.28 mm.

? *CALANUS CARINATUS* Kröyer.

*Calanus brevicornis* Lubb.

*Distribution.*—

At 350 fms. (35 l), one specimen.

Between 750– 500 fms. in 2 out of 4 hauls, with	.3	Average specimens per 100-fathom haul.
1000– 750	3      3	
1250–1000	2      2	
1500–1250	1      1	
2000–1500	1      1	

With (1915) has satisfied himself, by examination of Kröyer's original specimen, that *C. carinatus* and *C. brevicornis* are identical.

This is one of the most markedly deep-water species in the collection. As no adults were present—most of the specimens being in stage V—it is not possible to say definitely whether this is *C. carinatus* or, as its habitat suggests, a new species. As far as the form of cephalothorax goes, it agrees very well with *C. brevicornis* as figured by Giesbrecht.

Length, stage V, 2.4 mm.

*CALANUS GRACILIS* Dana.

*Distribution.*—

By day in				By night in			
Depth.	0 fms.	5 out of 9 hauls, with	1.4	4 out of 4 hauls, with	.2	Per	
25	2	6	.4	6	6	1.8	cent.
50	6	7	3.5	5	5	1.8	of
75	3	3	3.3	8	8	1.0	average
100	12	12	3.8	9	9	1.1	haul.

At 150 fms. in 0 out of 1 haul, with 0

200	2	2	1.7	Per cent. of average haul.
250	2	2	.75	
300	1	1	.56	
350	1	1	.3	

Between 150– 50 fms. in 1 out of 1 haul, with 4				Average specimens per 100-fathom haul.
200– 100	3	6	2.3	
250– 150	2	3	.7	
300– 200	1	3	.3	
400– 300	1	3	.3	
500– 400	1	3	1.0	
750– 500	1	4	.4	
1000– 750	0	3	0	
1250–1000	2	2	3.6	
1500–1250	1	1	.4	
2000–1500	1	1	.2	

Scarce by day in the upper 25 fathoms, but frequent between 50 and 100 fathoms. At 25 fathoms the numbers show an increase by night, but from 50 to 100 fathoms there is no appreciable change, the apparent decrease being due to the increase in the total catch of all species by night. From 100 fathoms the numbers decrease gradually down to 750, and an apparent increase again at 1250–1000 fathoms seems to be due to an accumulation of dead specimens, most of those taken below 1000 fathoms being apparently dead.

The numbers present do not show any great variation, the highest proportions recorded in any one haul at 50 fathoms being 14 per cent., at 75 fathoms 6·9 per cent., and at 100 fathoms 8·8 per cent.

Length, ♀, 3·5–3·9 mm.

#### MEGACALANUS PRINCEPS Wolfenden.

*Macrocalanus longicornis* G. O. Sars, 1905.

*Megacalanus longicornis* G. O. Sars, 1924.

As this species is not congeneric with that described by Brady as *Calanus princeps*, it is right that Wolfenden's specific name, given in 1904, should replace that given by Sars, which I have used in a former paper (1908).

#### *Distribution.*—

350 fms. (1 specimen, V).

Between 500–250 fms. (Pilchard net) (1 specimen, ♀).

750–500 fms. in 2 out of 4 hauls (2 specimens, ♀, IV).

1000–750 2 3 (2 „ ♀, V).

The range seems to be from 350 fathoms to below 750, probably to 1000 fathoms.

Length, ♀, 9·0–9·2 mm.; V, 8·7 mm.; IV, 5·7 mm.

#### EUCALANUS ELONGATUS (Dana).

#### *Distribution.*—

Depth.	By day in				By night in			
0 fms.	3 out of 9 hauls,	with	·5	} Per cent. of average haul.	1 out of 4 hauls,	with	·3	} Per cent. of average haul.
25	5	6	·3		2	6	·05	
50	5	7	1·0		5	5	·16	
75	2	3	·16		4	8	·02	
100	8	12	1·3		6	9	·04	

At 150 fms. in 1 out of 1 haul (1 specimen).

200 1 2 (1 „ ).

250 2 2 (2 specimens).

300 1 1 haul, with ·25 per cent.

350 1 1 (1 specimen).



Between 150- 50 fms. in 0 out of 1 haul, with 0				
200-100	3	6	.5	Average specimens per 100-fathom haul.
250-150	0	3	0	
300-200	1	3 (1 specimen)		
400-300	3	3 hauls, with 1.3		
500-400	3	3	5	
750-500	4	4	1.3	
1000-750	2	3	1.6	
below 1000	0	4	0	

Not much reliance can be put on the records of vertical distribution, as it is evident from the individual townettings that the horizontal distribution is very irregular, and there are not enough records to neutralise the discrepancies which arise in consequence. Thus on Station 21, in a haul at 100 fathoms *E. elongatus* formed more than 10 per cent. of the total, and at 50 fathoms 5 per cent., and in a vertical haul of 500-400 fathoms ten specimens were taken. On the other hand, on Station 35, out of nine hauls made in the epiplankton it was only represented, by single specimens in the samples examined, in two hauls.

Below 100 fathoms we may say that it only occurs in very small numbers, and below 300 fathoms all the specimens found were apparently dead. Above 100 fathoms it is more often present than absent, and may occasionally occur in large numbers, but there is no difference between its day and night distribution.

Esterly (1911 *a*) has made a study of the distribution of this species in the San Diego region, and has obtained results which differ considerably from mine. His closing nets, both vertical and horizontal, show a day plurimum between 150 and 250 fathoms. At early nightfall he finds a decrease at *all* depths, a conclusion which at first sight appears to be a *reductio ad absurdum*. One explanation which he suggests is that during this time a horizontal scattering takes place. This implies that shoals were met with during the day, and that sufficient hauls were not made to counteract the irregularities due to chance encounter with them, an explanation which is virtually identical with that suggested above. From his vertical net hauls he considers that there is evidence of an upward movement by night.

Length, ♀, 6.4 mm.

#### EUCALANUS CRASSUS Giesbr.

##### *Distribution.*—

Depth.	By day in			Per cent. of average haul.	By night in			Per cent. of average haul.
0 fms.	6 out of 9 hauls,	with	.5		1 out of 4 hauls,	with	.15	
25	4	6	.3	} Per cent. of average haul.	1	6	.02	} Per cent. of average haul.
50	4	7	.2		4	5	.3	
75	1	3	.07		2	8	.01	
100	9	12	.5		3	9	.02	

At 150 fms. in 0 out of 1 haul.

200	2	2	(2 specimens).
250	2	2	hauls, with .29 per cent.
300	1	1	.62
350	1	1	.37

Between 150- 50 fms. in 0 out of 1 haul.

150-100	1	1	(1 specimen).
200-100	2	6	(2 specimens).
250-150	0	3	
300-200	0	3	
400-300	1	3	(1 specimen).
500-400	0	3	
750-400	2		4 hauls, with .3 specimens per 100 fms.

It is apparently generally distributed in very small numbers from the surface to below 500 fathoms with no definite maximum or diurnal movement.

Length, ♀, 3.4-3.6 mm. ; ♂, 3.4-3.5 mm.

#### RHINCALANUS NASUTUS Giesbr.

##### *Distribution.*—

Depth.	By day in				By night in			
0 fms.	7 out of 9 hauls, with	7.8	} Per cent. of average haul.		3 out of 4 hauls, with	2.9	} Per cent. of average haul.	
25	4	6			5	6		
50	7	7			4	5		
75	3	3			7	8		
100	12	12			9	9		

At 150 fms. in 1 out of 1 haul, with	6.7	} Per cent. of average haul.
200	2	
250	2	
300	1	
350	1	

Between 150- 50 fms. in 1 out of 1 haul, with	44	} Average specimens per 100-fathom haul.
200- 100	6	
250- 150	3	
300- 200	3	
400- 300	3	
500- 400	3	
750- 500	4	
1000- 750	3	
1250-1000	2	
1500-1250	1	
2000-1500	0	

The epiplankton figures seem to indicate an increase during the day, but as this species, like *Eucalanus elongatus*, has a very irregular horizontal distribution, varying by day from 40 per cent. to less than one per cent. at 50 fathoms and from 29 per cent. to less than one per cent. at 100 fathoms, it is very probable that this is not a true diurnal movement. There is a plurimum, as shown by both vertical and horizontal nets, at about 200-300 fathoms and

a sudden decrease below 400 fathoms, many of the specimens below that depth being dead. Esterly's (1912) figures from the San Diego region also show a plurimum between 200 and 300 fathoms.

Length, ♀, 4·15–4·8 mm.

*MECYNOCERA CLAUSI* I. C. Thompson.

*Distribution*.—Taken once at the surface out of nine hauls with net 180. It also occurred at 25, 50, 75, and 100 fathoms, being taken in nine hauls out of eighteen made with net 65 and in one haul out of thirty-six with net 60, with from one to three specimens in the samples examined.

Length, ♀, 1·2 mm.

*PARACALANUS PARVUS* (Claus).

*Distribution*.—As stated above, the gatherings made with nets of 60 mesh gave an average for this species of ·19 per cent. of the total number of specimens per haul, while in those made with 65 mesh it amounted to 8·5 per cent. Taking 60 mesh as the standard, the specimens taken with 65 mesh must be reduced to 2·2 per cent. of their total to make the nets comparable. This has been done in the following table:—

Net 180.		By day in		Per cent. of aver- age haul.	By night in		Per cent. of aver- age haul.
At	0 fms.	5 out of 6 hauls, with 6·2			3 out of 3 hauls, with 10·3		
Nets 50 & 65.							
At	0 fms.	5 out of 9 hauls, with ·4		3	4	·12	
	25	4	6 ·6	6	6	·28	
	50	2	7 ·06	2	5	·02	
	75	1	3 (1 specimen)	1	8	·01	
	100	5	12 hauls, with ·04	6	9	·04	

Below 100 fathoms the closing nets used (36 and 45) were such as would only retain *P. parvus* by accident, consequently their negative records have no significance. They do, however, give us positive evidence of its occurrence in small numbers down to below 1000 fathoms.

Between 200–100 fms. in 1 out of 6 hauls (1 specimen).			
250–150	3	3 hauls, with 2	} Average specimens per 100- fathom haul.
500–200	0	9	
750–500	2	4	
1000–750	1	3	
1250–1000	1	2 hauls (2 specimens).	

A well-marked maximum occurs in the upper twenty-five fathoms of the epiplankton, with no indication of diurnal migrations, the numbers at 50 fathoms being about one-tenth of those at 25 fathoms. This agrees with its vertical distribution as seen in water of less than 100 fathoms round the Irish coast.

Length, ♀, ·72–1·05 mm,

*CALOCALANUS STYLIREMIS* Giesbr. (Pl. 5. figs. 5, 6.)

*Distribution*.—As the small size of this species makes its capture by any of the nets, except those of 180 and 65 mesh, very improbable, I have only taken those nets into account in recording the distribution of this and the next following species down to 100 fathoms.

0 fms. absent.				} Per cent. of average haul.
25	in 6 out of 8 hauls, with			
50	1	1	·3	
75	7	8	2·0	
100	1	1	·43	

One specimen at 200 fms.

One specimen between 200–300 fms.

Length, ♀, ·8–·85 mm.

There are some small differences in the form of the cephalothorax and abdomen between this species and that described by Giesbrecht (1892). The cephalon is not so flattened anteriorly and the body is slightly less robust in dorsal view (Pl. 5. fig. 5). The furcal rami are divergent instead of being parallel as in Giesbrecht's figure. The segmentation between the 2nd and 3rd abdominal segments (Pl. 5. fig. 6) is very faintly indicated, and in most cases is completely covered by the genital segment. The 5th feet agree with Giesbrecht's description in being 3-jointed, with a simple terminal spine with four or five minute spinules at its base.

The Adriatic form of *C. styliremis*, as figured by Fruehtl (1923), seems to be similar to that described above, though slightly smaller (·59–·66 mm.).

*CALOCALANUS CONTRACTUS*, sp. n. (Pl. 5. figs. 1–4.)

*Description*.—Length, ♀, ·75–·78 mm. Resembles *C. styliremis* in general appearance (Pl. 5. figs. 1, 2), but is much more slender, the length of the cephalothorax being slightly more than three times its width instead of 2½ times. Abdomen (Pl. 5. fig. 4) very short, 3-jointed; genital segment very broad, with two very noticeable circular spermathecae widely separated; 2nd segment very short, only exposed dorsally and completely covered by the genital segment in ventral view, so that in some specimens its presence could not be made out; anal segment about twice as wide as long, anal flap rounded, furcal rami spreading at about 75°, widely separated, a little longer than wide, with four terminal setae, the two outermost much slenderer than the inner ones, and one fine inner edge seta; setae broken off in all specimens.

Antennular joints in ·01 mm. :—

No.:	1	2	3	4	5	6	7	8–9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Size:	4	7	4	4	3·5	4	4	5·5	3	3	3·5	3·5	4	4	4·5	5	5	6	6·5	6·5	8	10	8	18

These lengths in general correspond to those of *C. styliremis* as given by Giesbrecht except that the terminal joint is more than twice as long as the penultimate and the first ten joints are slightly longer. The segmentation

between joints 1-2 is distinct and between 8-9 only faintly indicated. Antennæ with *re* equal to *ri*, *re* with all its seven joints indicated, the 7th joint being about two-thirds the combined lengths of the 1st and 2nd; mandible, 1st and 2nd maxillæ, maxillipede and swimming feet agree, as far as can be made out, with those of *C. styliremis*. The 5th feet (Pl. 5. fig. 3) are 3-jointed as in *C. styliremis*, but the terminal joint bears two setæ longer than the joint and one or two subterminal spinules.

This species might at first sight be mistaken for a rather slender example of *C. styliremis*, but its smaller size and less divergent furca help to identify it.

*Distribution*.—Only found in the epiplankton, but no net fine enough for its capture was used below 100 fathoms.

The captures by net 65 are as follows:—

At 0 fms. absent.				} Per cent. of average haul.
25	in 5 out of 8 hauls, with		15	
50	1	1	1.1	
75	4	7	.18	
100	1	1	.12	

These figures show that *C. contractus* resembles *C. styliremis* in its distribution, but is only one-third as numerous.

*CALOCALANUS TENUIS*, sp. n. (Pl. 5. figs. 7-12.)

*Description*.—Length, ♀, 1.18-1.22 mm. General appearance (Pl. 5. figs. 7, 8) suggesting a miniature *Calanus*. Cephalothorax slender, fusiform, cephalon vaulted, fused with *th.* 1. Abdomen 3-jointed. Genital segment about as broad as long, very slightly protuberant ventrally, slightly longer than the anal segment; 2nd abdominal segment about one-third as long as the genital segment; furcal rami about as broad as long, furcal setæ broken in all specimens examined. Rostrum with two slender filaments arising from a slightly projecting base. First antenna with terminal joints missing in all specimens.

Proportional length of joints 1-17 in .01 mm. :—

No. ....	1	2	3	4	5	6	7	8+9	10	11	12	13	14	15	16	17
Size ....	5.3	7.6	2.8	3.7	3.5	3.7	3.5	5.9	2.5	3.0	3.4	3.8	4.0	4.5	4.5	4.6

Second antenna, mandible, 1st and 2nd maxillæ and maxillipede of the same general form as in *Calanus*.

Swimming feet: 1st foot (Pl. 5. fig. 9) with 3-jointed *re* and 2-jointed *ri*, the separation between *re* 2 and *re* 3 is not as definite as that between *re* 1 and *re* 2; 2nd to 4th feet (Pl. 5. figs. 10, 11) with 3-jointed *re* and *ri*. *re* of 1st foot with 0, 0, 2 *se* and 1, 1, 4 *si*; *re* of 2nd and 3rd feet with 1, 1, 2 *se* and 1, 1, 5 *si*; *re* of 4th foot with 1, 1, 2 *se* and 0, 1, 5 *si*. *ri* of 1st foot with 0, 0, *se* and 1, 4 *si*; *ri* of 2nd to 4th feet with 0, 0, *se* and 1, 2, 5 *si*. Proportional lengths of joints and spines of the feet as shown in the figures.

A transverse row of slender spines runs across *ri* 2 of the 2nd to 4th feet, and there are three or four similar spines on the inner margin of the same joint. A faint trace could be seen in one specimen of the lamellar spines of the *re* which Giesbrecht describes in this genus.

Fifth foot (Pl. 5. fig. 12) with two basal joints and a more slender 2-jointed exopodal portion. The terminal joint is about  $2\frac{1}{4}$  times as long as the preceding joint, and bears a small distal outer edge tooth, a terminal spine about as long as the joint, and two distally-situated inner edge setæ a little longer than the joint; at the base of these setæ are about three minute spinules.

*Distribution*.—Not taken below 100 fathoms.

Being slightly larger than *C. styliremis*, it has been taken several times with nets of mesh 60 as well as 65. The records from both nets are given below separately:—

NET 65.				NET 60.			
0 fms. absent.				absent.			
25	in 5	out of 8	hauls, with .18	} % of aver- age haul.	in 2	out of 4	hauls, with .03
50	1	1	.3		3	11	.02
75	5	8	.04		1	3	.03
100	1	1	.12		4	20	.01

#### Genus CLAUSOCALANUS.

All the specimens of *Clausocalanus* seemed at first sight to belong to *C. arcuicornis*, but further investigation showed that they almost all fell into three size groups, of which the larger two overlapped. The total lengths of these groups are approximately .9–1.05 mm., 1.2–1.4 mm., and 1.4–1.6 mm. The carapace lengths, which can be measured much more accurately than the total lengths, were measured in samples from sixteen gatherings taken at random, and gave the following numbers at sizes, measurements above .85 mm. being in 0.4 mm. groups and those below .85 mm. in .02 mm. groups:—

Size .....	.62	.64	.66	.68	.70	.72	.74	.76	.78	.80	.82	.84	.86
No. ....	1	9	20	30	67	20	11	8	2	—	—	—	—
Size .....	.90	.94	.98	1.02	1.06	1.10	1.14	1.18	1.22	1.26	1.30		
No. ....	4	21	47	40	33	33	56	106	63	49	12		

The specimens of the smallest group have proportionately a slightly longer abdomen and furcal rami than those of the larger groups, and consequently seem entitled to specific recognition. They are described below as *Clausocalanus pergens*. The larger series of measurements when plotted gives a bimodal curve which at once suggests the presence of two overlapping size groups, which, however, as far as my observations go, are otherwise indistinguishable. These two larger groups are evidently the *Clausocalanus arcuicornis* auctorum for which Giesbrecht gives the size of 1.15–1.6 mm. A few specimens, a fourth group, of very minute size (.75–.82 mm.) were present. For these I have proposed the name *Clausocalanus paululus*. It

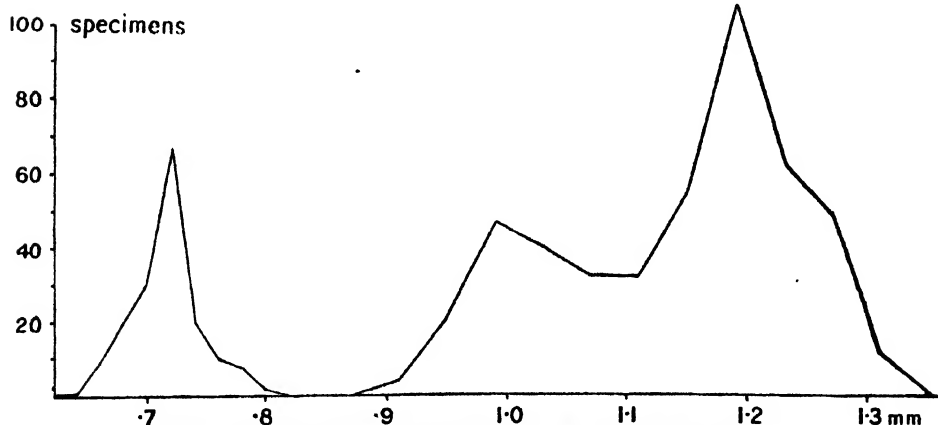
should be noted that the differences in form between the three species here recognized are trifling and much less than those which separate them collectively from *C. furcatus*.

Fruchtl (1923) has recorded a range of sizes of *C. arcuicornis* in the Adriatic corresponding to the lower half of that given above, and recognizes those specimens corresponding in size to *C. pergens* as being a genuine dwarf form.

*CLAUSOCALANUS ARCUICORNIS* (Dana). (Pl. 6. figs. 1-3.)

*Distribution*.—There seems to be some evidence that the two size groups, mentioned above, which I have included in this species are differently distributed in the epiplankton, the larger group (1.4-1.6 mm.), which I refer to as Group A, being relatively most plentiful at the surface and diminishing in

FIG. 1.



*Clausocalanus arcuicornis* and *C. pergens*, graph of carapace lengths.

abundance down to 100 fathoms, while the smaller group (1.2-1.4 mm.), referred to as Group B, is almost absent from the surface, and shows little variation in the proportional numbers from 25 to 100 fathoms.

I have tried to separate the two groups in tabulating the distribution in the epiplankton, but, as in practice it is impossible to separate the immature stages, they, and also males when present, have been divided in each gathering in the proportion which was found to exist between the adult females of the groups in the same gathering. Taking an average of all depths down to 100 fathoms, Group A is nearly ten times as numerous as Group B.

Below 100 fathoms the numbers of the two groups are nearly equal, Group B being slightly the more abundant at all depths, and it has not seemed worth while to separate them.

## GROUP A.

Net 180.		By day in				By night in			
0 fms. 6 out of 6 hauls, with 27.5						3 out of 3 hauls, with 44.7			
Nets 60 & 65.				Per cent. of average haul.			Per cent. of average haul.		
0 fms. 9	9	61.5	4		4	51.5			
25	5	6	30.8		5	6		18.7	
50	7	7	28.8		5	5		8.0	
75	3	3	19.1		8	8		4.2	
100	11	12	14.3	9	9	3.8			

## GROUP B.

Net 180.		By day in		Per cent.	By night in		Per cent.
0 fms.		1 out of 6 hauls, with .12			2 out of 3 hauls, with .38		
Nets 60 & 65.				of average haul.			of average haul.
0 fms.		3	9		1	3	
25		3	6		5	6	
50		5	7		5	5	
75		2	3		7	8	
100		9	12	9	9		

## GROUPS A and B.

At 150 fms. in 1 out of 1 haul, with 6.6				} Per cent. of average haul.
200	1	2	3.2	
250	2	2	2.8	
303	1	1	1.4	
350	1	1	4.4	

Between 150- 50 fms. in		1 out of 1 haul, with 30		Average specimens per 100-fathom haul.
200- 100	6	6	20	
250- 150	3	3	39	
300- 200	3	3	10.7	
400- 300	2	3	3.3	
500- 400	1	3	1.0	
750- 500	3	4	1.0	
1000- 750	3	3	2.1	
1250-1000	2	2	2.6	
1500-1250	1	1	(1 specimen).	
2000-1500	1	1	(1 " ).	

It is not impossible that we should see in the two groups included under *C. arcuicornis* a case of variation due to development in regions differing in temperature or some other environmental condition, such as has been demonstrated in Danish waters by Jespersen and Miss Adler (1920). The size limits of the two groups are well within those found by these observers in the case of *Pseudocalanus elongatus*, and it may be that the greater abundance of the larger form at the surface is the result of its having been brought by a surface drift from some other locality. But against this view may be mentioned the fact that, judging by the large number of immature specimens present, development was proceeding *in situ*, and the probability that individuals brought from elsewhere by a surface drift would soon resume their normal vertical distribution.



Taken together they seem to represent the form described by Claus (1863) as *C. mastigophorus* and Giesbrecht as *C. arcuicornis*, with which they agree in most points. The 5th feet of the ♀ (Pl. 6. fig. 3) were, however, noticeably shorter than is shown in Giesbrecht's figure, the third joint being shorter than the first and second together. Giesbrecht's figure agrees more nearly with those of the species described below as *C. pergens*.

*CLAUSOCALANUS PERGENS*, sp. n. (Pl. 6. figs. 4-6.)

*Description*.—Length, ♀, .9-1.05 mm. Body (Pl. 6. fig. 4) of the same general form as in *C. arcuicornis*, but slightly more rounded in lateral view, abdomen slightly longer, being contained  $2\frac{2}{3}$  times in the length of the cephalothorax instead of 3 times or more, usually curved in lateral view, whereas in *C. arcuicornis* it is generally straight. Furcal rami (Pl. 6. fig. 5) about  $1\frac{1}{2}$  times as long as wide. 1st antenna slightly longer in total length, measured along the curve, than the cephalothorax. In *C. arcuicornis* it is about as long as the cephalothorax. Mouth appendages and swimming feet with no noticeable points of difference from those of *C. arcuicornis*. 5th feet (Pl. 6. fig. 6) with the third joint about as long as the first and second together. In this they agree with the 5th feet of *C. arcuicornis* as figured by Giesbrecht (1892).

*Distribution*.—

Net 180.		By day in		By night in			
0 fms.		3 out of 6 hauls, with 7		3 out of 3 hauls, with .3			
Nets 60 & 65.							
0 fms.	5	9	.93	4	4	.2	
25	6	6	.8	6	6	.8	
50	7	7	1.5	5	5	.55	
75	3	3	.89	8	8	.56	
100	10	12	.94	9	9	.4	
							Per cent. of average haul.

At 150 fms. in 1 out of 1 haul, with .27					
200	1	2	.7	Per cent. of average haul.	
250	1	2	.05		
300	1	1	(1 specimen)		
350	1	1	.3		

Between	150- 50 fms.	in 0 out of 1 haul.			
	150- 100	0	1	Average specimens per 100-fathom haul.	
	200- 100	5	6 hauls, with 8.2		
	250- 150	3	3		
	300- 200	1	3		
	400- 300	1	3	3.7	
	500- 400	1	3	9	
	750- 500	2	4	1.1	
	1000- 750	3	3	1.3	
	1250-1000	1	2	.4	
	1500-1250	1	1	.8	

Owing to the small size of this species, about 94 per cent. of the specimens of which will, as shown above, pass through the meshes of net 60, it is difficult to draw any definite conclusions as to its vertical distribution. There are indications that it may occur in shoals at the surface during the day, but that otherwise its distribution in the epiplankton is uniform both by day and night. It is common and probably abundant down to 500 fathoms, and occurs in diminishing numbers down to below 1250 fathoms.

It may be mentioned that specimens have occasionally been taken in small numbers in the epiplankton off the south and west coasts of Ireland.

*CLAUSOCALANUS PAULULUS*, sp. n. (Pl. 6. figs. 7-12.)

*Description*.—Length, ♀, .75-.82 mm.; average 79 mm. Body (Pl. 6. fig. 7) slightly stouter than in *C. pergens*; cephalon more rounded; rostrum curved downwards as in *C. pergens*. Abdomen (Pl. 6. fig. 8) slightly longer than one-third of the cephalothorax, curved in preserved specimens, length of segments as in *C. arcuicornis*; furcal rami (Pl. 6. fig. 12) slightly shorter than the anal segment and about  $1\frac{1}{2}$  times as long as wide. First antenna just reaching to the beginning of the genital segment, in actual length slightly shorter than the cephalothorax, jointing as in *C. arcuicornis* except that the last joint (24-25) is slightly longer than the two preceding ones (22+23) taken together. Appendages and swimming feet (Pl. 6. figs. 9, 10) similar to those of *C. arcuicornis*, but with only four teeth on the distal end of the second basal joint of the 2nd-4th feet. These teeth are similar on all feet; the outer edge spine of *re* 1 is also shorter than in *C. arcuicornis*. 5th feet (Pl. 6. fig. 11) of the same type as in *C. pergens*, the third joint being about as long as the first and second together.

These characters seem insignificant in themselves, and I would not have ventured to regard them as specific were it not for the small size of the species, which probably precludes it from mating except with a male of corresponding size.

*Distribution*.—This minute form was occasionally found in company with the other species of *Clausocalanus*. It was evidently not a surface form, as it was only taken once, one specimen, in the fine-meshed surface nets out of nine hauls. It occurred once, one specimen, at 100 fathoms in the nets of 60 mesh, and in the nets of 65 mesh it was taken as follows:—

0 fms. in	0 out of 4 hauls, with	0	} Average specimens per sample examined,
25	3	8	
50	1	1	
75	2	8	
100	1	1	
		6	

A range from 0 to at least 100 fathoms, with numbers increasing with the depth, is indicated by these records.

*OTENOCALANUS VANUS* Giesbr.*Distribution.*—

Depth.	By day in					By night in				
0 fms.	4 out of 9 hauls,	with	.18	} Per cent. of aver. haul.	2 out of 4 hauls,	with	.1	} Per cent. of aver. haul.		
25	5	6	2.5		6	6	4.9			
50	7	7	5.4		5	5	1.1			
75	3	3	10.4		8	8	3.0			
100	12	12	4.7		9	9	2.8			
At 150 fms. in	1 out of 1 haul,	with	3.7	} Per cent. of average haul.						
200	1	2	2.0							
250	2	2	.93							
300	1	1	.8							
350	1	1	.96							
Between 150-	50 fms. in	1 out of 1 haul,	with 9.0	} Average specimens per 100-fathom haul.						
200- 100		6	6		7.8					
250- 150		3	3		14.7					
300- 200		1	3		.7					
400- 300		1	3		3.7					
500- 400		2	3		2.3					
750- 500		3	4		.8					
1000- 750		2	3		.4					
1250-1000		0	2							
1500-1250		1	1 haul (2 specimens, dead).							

Comparison of the catches of this species with nets 60 and 65 showed that net 65 took approximately three times as many as net 60. The catches with net 65 have accordingly been reduced to one-third before calculating the percentages in the epiplankton given in the above table. This correction makes a considerable reduction in the averages at 25 and 75 fathoms, and has also been taken into account in calculating the averages of other species at those depths, but at other depths the alteration is slight. The size of the female of this species (.92-1.15 mm.) approaches the critical size for net 60, and the coarser vertical nets must have allowed the escape of a large number of specimens. Although it is almost always present, the numbers in individual hauls are very variable. Sometimes it forms a very high proportion of the catch, *e. g.* 25 per cent. at 75 fathoms by day (32 *g*), and 23 per cent. at 50 fathoms by day (32 *a*), both hauls with net 60. There is some indication of a maximum at 250-150 fathoms, but, considering its shoaling habits, the most that can be said with certainty is that it is plentiful down to about 200 fathoms.

In almost all the hauls at and below 100 fathoms males were much more numerous than females. This may be due in part to the selective action of the net, owing to the slightly larger size of the males, but allowing for this fact, it seems to represent a real phenomenon, as in all the gatherings above 100 fathoms in which the numbers of each were counted the females were more numerous than, or in one instance equal to, the males.

Length, ♀, .92-1.16 mm.; ♂, 1.20-1.26 mm.

*PSEUDOCALANUS ELONGATUS* (Boeck).

*Distribution*.—In three hauls out of thirteen at the surface with an average of .1 per cent. in all hauls. Twice at 25 fathoms, three times at 75 fathoms, once at 100 fathoms, and once at 350 fathoms, single specimens each time. Taken eight times with net 65 and once with net 60.

Apparently a very scarce species in these waters, occurring most often at the surface and probably drifted from elsewhere.

Length, ♀, 1.25–1.3 mm.

*MICROCALANUS PYGMÆUS* (G. O. Sars).

*Distribution*.—Occurred three times out of eleven hauls at 75 fathoms with percentages at .78, .73, and .08, the successful hauls being all on Station 35, and once at 100 fathoms with .17 per cent (36 e). Single specimens were found at 150 fathoms (36 f) and 200 fathoms (36 g). The evidence for the absence of this species at other depths is of no value, as it is much too small to be retained by net 60 unless present in very large numbers.

I am unable to distinguish clearly between *Microcalanus pygmaeus* and *M. pusillus*. If the species are distinct these specimens ought perhaps to be referred to the latter, with which they agree in the form of the genital segment.

Length, ♀, .7–.72 mm.

*SPINOCALANUS ABYSSALIS* Giesbr.*Distribution*.—

Not found in the epiplankton.

At 200 fms. in 1 out of 2 hauls, with				} Per cent. of average haul.
250	2	2	.33	
			.35	
300	1	1	1.9	
350	1	1	1.1	

Between	150–	50 fms. in	0 out of 1 haul, with	0	} Average specimens per 100-fathom haul.
	200–	100	2	6	
	250–	150	2	3	
	300–	200	0	3	
	400–	300	2	3	
	500–	400	1	3 (1 specimen)	
	750–	500	3	4 hauls, with 1.9	
	1000–	750	3	3	
	1250–	1000	1	2 (1 specimen)	
	1500–	1250	0	1 haul, with 0	
	2000–	1500	1	1 (1 sp., dead)	

There seems to be a fairly uniform distribution of this species from about 200 fathoms to 1000 fathoms with smaller numbers up to 100 fathoms and down to 2000.

I have here restricted the name *S. abyssalis* to specimens of from 1.45 to 1.6 mm. in length, and have proposed a new varietal name for a smaller group

measuring .95 to 1.1 mm. Giesbrecht's original Pacific specimens measured 1.1–1.25 mm., and are intermediate in size between the two size groups which were found in these gatherings. With, using, it seems, coarser nets, records the size of his specimens as 1.73–1.86 mm., so that there seems to exist a continuous series from .95 to 1.86 mm., and it may be that the separation of the variety may not be possible in all localities. I have already (1908) recorded its occurrence in deep water off the west coast of Ireland.

Lysholm and Nordgaard (1921) have suggested that this species is of arctic origin, and transported southwards by under currents of arctic water. It appears to have a continuous range from the Bay of Biscay to the Arctic in the deep water of the Atlantic, but the numbers in the southern part of its range are large enough to make it probable that it is a permanent inhabitant and not an immigrant.

*SPINOCALANUS ABYSSALIS* var. *PYGMÆUS* nov.

*Distribution.*—

At 200 fms. in	1	out of 2 hauls, with	.05	} Per cent. of average haul.
250	1	2	(1 specimen)	
300	1	1 haul, with	.12	
350	1	1	.81	
Between 150–	50 fms. in	0 out of 1 haul, with	0	} Average specimens per 100-fathom haul.
200–	100	1	6	
250–	150	2	3	
300–	200	1	3	
400–	300	3	3	
500–	400	3	3	
750–	500	4	4	
1000–	750	2	3	
1250–	1000	1	2	(1 specimen).
1500–	1250	1	1	(1 „ ).

Above 300 fathoms this form is less than half as plentiful as the large *S. abyssalis*, but below that depth it becomes much more numerous, reaching a well-attested average of over seven specimens per 100 fathoms vertical haul between 500 and 300 fathoms. This must indicate a considerable abundance when the large mesh of the nets is taken into account.

This difference in distribution from the larger form coupled with the difference in size persisting over a wide area, from the Bay of Biscay to Ireland, makes it almost certain that we are here dealing with two distinct races, if not species.

Length, ♀, .95–1.08 mm.

*SPINOCALANUS MAGNUS* Wolfenden.

*Distribution.*—

At 250 fms. in	1	out of 2 hauls, with	.15	} Per cent. of average haul.
300	1	1	.64	
350	1	1	1.6	

Between	400- 300 fms. in 2 out of 3 hauls, with 4				
	500- 400	2	3	3	Average specimens per 100-fathom haul.
	750- 500	2	4	1.2	
	1000- 750	3	3	1.2	
	1250-1000	0	2	0	
	1500-1250	0	1	0	
	2000-1500	1	1	.4	

The optimum clearly lies at about 300-500 fathoms, with an upper limit clearly marked at 250 fathoms and a normal downward extension to about 1000 fathoms; the two specimens taken at 2000-1500 fathoms were probably sinking. This agrees with previous records, by Wolfenden, Damas and Koefoed, With and myself, from more northern waters.

The size of these specimens, 2.58-2.67 mm., is slightly less than that of those from farther north (Wolfenden (1904), 2.75 mm.; With (1915), 2.8 mm.; Farran (1905), 2.9 mm.).

#### SPINOCALANUS SPINOSUS Farran.

##### *Distribution.*—

At 350 fathoms in 1 out of 1 haul, with .37 per cent.

Between	150- 50 fms. in 0 out of 1 haul.				
	200-100	1	6 hauls (1 specimen).		
	250-150	1	3 (1 „ )		
	300-200	0	3		
	400-300	2	3 hauls, with 2.7	Average specimens per 100- fathom haul.	
	500-400	3	3		
	750-500	4	4		
	1000-750	2	3		
					.53

The optimum for this species is at about the same depth, 300-500 fathoms, as that of *S. magnus*, but the range upwards and downwards is more restricted and in reduced numbers.

Length, ♀, 1.8-1.86 mm.

#### MIMOCALANUS CULTRIFER Farran.

##### *Distribution.*—

At 200 fms. in 1 out of 2 hauls, with .5					
250	2	3	1.3	Per cent. of average haul.	
300	1	1 (1 specimen)			
350	1	1 haul, with .3			
Between	200-100 fms. in 2 out of 6 hauls, with .8				
	250-150	2	3	1.3	Average specimens per 100-fathom haul.
	300-200	0	3	0	
	400-300	1	3 (1 specimen)		
	500-400	3	3 hauls, with 2.7		
	750-500	2	4	1.3	
	1000-750	1	3	.4	

The range seems to be from 200 to below 750 fathoms, with an optimum at 400–500 fathoms.

Length, ♀, 1.3–1.6 mm. ; average 1.35 mm.

#### MONACILLA TYPICA G. O. Sars.

*Oxycalanus spinifer* Farran, 1908.

##### Distribution.—

Horizontal nets.—250 fms., one, stage V ; 350 fms., one, stage V.

Vertical nets.— 750–500 fms. in 3 out of 4 hauls, with .6 spec. per 100 fms.  
 1000–750                      1                      3                      .53                      „                      „

Length, ♀, 2.24–2.28 mm. ; stage V, ♀, 1.92–1.98 mm.

In a specimen of 2.24 mm. the cephalothorax to base of abdomen measured 1.72, the abdomen .52 mm., *i. e.* 3.3 times in length of cephalothorax.

The examination of these specimens allows me to supplement and correct in some points my original description of *Oxycalanus spinifer*.

The abdomen is slightly asymmetrical, protruding a little on the right side. The left 4th foot, which was missing in the original specimen, has a transverse row of long acicular spines on the posterior face of the 1st basal joint. These spines are absent on the right foot. The appendage which I described and figured as the 3rd foot is the right 4th foot, and the two rows of slight slender spines, described as being on the 2nd basal joint of the 4th foot, are in reality on the 1st basal of the 3rd foot. The 1st antenna when pressed against the body reaches almost to the beginning of the anal segment.

Two species closely resembling *M. typica* have recently been added to this genus under its synonym *Oxycalanus*, but in view of Sars's recent figures and the corrections made above, their distinctness is doubtful. They are *O. semispinus* A. Scott (1909) from the Dutch East Indies and *O. gracilis* Wolfenden (1911) from the tropical Atlantic.

#### MONACILLA TENERA G. O. Sars. (Pl. 6. figs. 13, 14.)

*Hypicalanus gracilis* Wolfenden.

##### Distribution.—

Between	750–	500 fms. in 1 out of 4 hauls, with	.2	} Average specimens per 100- fathom haul.
	1000–	750	0      3      0	
	1250–	1000	2      2      5	
	1500–	1250	1      2      6.4	
	2000–	1500	1      1 haul (1 specimen).	

The normal range appears to be from 1000–1500 fathoms, consequently this species is the most definitely bathypelagic of any in the collection. Almost all the specimens appeared to have been dead for some time before capture. It is probable that at such depths dead specimens remain in existence for a

much longer period than in shallower water, being less exposed to attack by bacterial and other destructive agencies, and consequently the proportion of dead to living specimens will be much higher.

In spite of some small differences in form there seems to be no doubt that the 'Research' specimens are the same as those described by Sars and by Wolfenden from the 'Gauss' collections. The locality from which Wolfenden received his specimens is recorded as "in Porto Grande, St. Vincent, Kap Verden," which suggests a littoral provenance, and one of the Monaco captures recorded by Sars (Station 2197) was in a surface haul made a short distance north of the Azores, two others being from deep-water hauls made south and south-west of the Azores. It seems likely, however, that it is normally a deep-water form.

Length, ♀, 2.04-2.19 mm.

*ÆTIDEUS ARMATUS* (Boeck).

*Distribution* :—

By day in				By night in			
At 0 fms.	4 out of 9 hauls,	with .53	} Per cent. of average haul.	1 out of 4 hauls,	with .45	} Per cent. of average haul.	
25	3	6		3	6		
50	5	7		5	5		
75	3	3		7	8		
100	12	12		8	9		
At 150 fms. in 1 out of 1 haul, with 1.3							
200	2	2	} Per cent. of average haul.				
250	2	2					
300	1	1					
350	1	1					
Between	150-500 fms. in 1 out of 1 haul,	with .8	} Average specimens per 100-fathom haul.				
	200-100	6 6		2.8			
	250-150	3 3		1.3			
	400-200	0 6		0			
	500-400	1 3		.1			
	750-500	2 4		.2			
	1000-750	1 3	.4				

In gradually increasing numbers from the surface to 100 fathoms and thence in decreasing numbers to 200 fathoms, below which isolated individuals, usually immature, occasionally occur. The difference between the day and night catches at 75 and 100 fathoms is greater than can be explained by the incursion of other upward migrating species by night, but it is hardly large enough to be regarded as definite proof of a downward migration by night, and may be due to chance. The slight apparent increase below 400 fathoms is perhaps due to sinking specimens, as might be expected from a species which is moderately common in the epiplankton.

Wolfenden (1904) in the Faroe Channel found this species in 100 per cent. of the hauls at 100 fathoms, 83 per cent. at 200 fathoms, and 25 per cent. at 300 fathoms.



Length, ♀, 1·8–1·95 mm.; ♂, 1·53 mm. One specimen, a female, with a single symmetrical rostrum, evidently an abnormal form, was taken on Station 36 i in a 250–0 fathom haul.

*ÆTIDEUS GIESBRECHTI* Cleve.

*Distribution.*—

	By day in				By night in			
At 75 fms.	0 out of 3 hauls, with 0	} % of			2 out of 8 hauls (2 spec.)	} % of		
100	7	12	·3	av. haul.	5	9 hauls with ·07	av. haul.	
At 150 fms.	in 1 out of 1 haul, with ·1			} Per cent. of average haul.				
200	0	5	0					
250								
300								
350	1	1	·16					

Between 150–50 fms. in 1 out of 1 haul, with 1 per 100 fms.

Not below 150 fms. in vertical hauls.

Possibly the specimens in the 350 fathoms net were taken during its ascent; if this is so its range lies between 75 and 150 fathoms. It seems probable that it is a southern form drifted northwards.

Length, ♀, 2·04–2·05 mm.

*CHIRIDIUS ARMATUS* G. O. Sars.

*Distribution:*—

At 250 fms.	in 2 out of 2 hauls, with ·15			} Per cent. of average haul.
300	1	1	·47	
350	1	1	·3	
Between 150–50	in 0 out of 1 haul.			
200–100	in 1			6 hauls (1 specimen).
250–150	1			} Average specimens per 100- fathom haul.
300–200	3		3	
400–300	2		3	
750–400	0		7	
1000–750	1		3	

These figures seem small, considering its frequent occurrence off the west coast of Ireland. Its optimum range seems to be sharply restricted to between 200 and 400 fathoms; the isolated specimen at 1000–750 fathoms is probably a sinker. Lysholm and Nørdgaard regard this species as a boreal form brought south by undercurrents.

Length, ♀, 3·2–3·6 mm. The small size supports With's observation (1915) that northern specimens are larger than southern.

Developmental stages: V ♀, 2·34–2·58 mm.; V ♂, 2·64–2·96 mm.; IV ♀, 1·86–1·98 mm.

*CHIRIDIUS POPPEI* Giesbrecht.

Four specimens were taken at 100 fathoms in three out of twenty-one hauls.

Two females each measured 1·92 mm., and two, stage V, 1·4 and 1·5 mm.

It seems safe to refer these specimens to *C. Poppei* described by Giesbrecht (1892) from the Mediterranean with a length of 1·8 mm. The small size and absence of rostrum distinguish it from other described species of the genus.

**CHIRIDIUS GRACILIS** Farran.

One specimen, stage IV ♀, without a rostrum, length 1·38 mm., was taken on Station 36 e, 350 fathoms.

This size would correspond to an adult of the size of *C. gracilis* (2·4–2·8 mm.). There seems to be some evidence that *C. gracilis* is a deep-water form, while *C. Poppei*, judging by the above records from 100 fathoms, is epiplanktonic.

**CHIRIDIUS MULTISERRATUS** (Wolfenden).

*Farocella multiserrata* Wolfenden, 1904.

*Farocella multiserrata* Farran, 1908.

*Chiridius nasutus* With, 1915.

*Ætideopsis multiserratus* G. O. Sars, 1924.

*Distribution.*—

750–500 fms., 34 e, one (IV); 34 f, two (♀, IV).

1250–1000 fms., 27 b, one (♀).

The females agree closely with With's description of *Chiridius nasutus*, and also with specimens of *F. multiserrata* from the west coast of Ireland, some of which had been identified by Dr. Wolfenden. With's excellent figures and description have now made clear the characters of this species.

Length, ♀, 2·64 mm. (cephalothorax, without spines 2·04; abdomen ·6) and 2·82 mm. (cephalothorax, without spines 2·16; abdomen ·66).

Stage IV ♀, 1·56 mm.

Females from the west coast of Ireland measured 2·6–3·0 mm.

**CHIRIDIELLA MACRODACTYLA** G. O. Sars.

*Distribution.*—Between 750–500 fms. in 2 out of 3 hauls, 2 specimens, both females.

Length, ♀, 2·56–2·8 mm.

**ÆTIDEOPSIS ROSTRATA** G. O. Sars.

*Distribution.*—750–500 fms., one specimen stage V; 1500–1250 fms., one specimen, ♀.

Length, ♀ 3·26 mm.; ♂ V, 2·28 mm. The rostrum is distinctly longer and more divergent than in *Chiridius multiserratus*, and the segmentation between the fourth and fifth thoracic segments is clearly marked. It does not seem to be the same as the *Æ. rostrata* of With.

**GAIDIUS TENUISPINUS (G. O. Sars).**

*Distribution*.—1000–750 fathoms, one specimen, stage IV ♂.

Length, stage IV ♂, 1.9 mm. With's measurement of stage IV ♂ of this species was 2.06 mm.

**GAIDIUS AFFINIS G. O. Sars.**

*Distribution*.—1250–1000 fathoms, one specimen, stage V ♂.

Length, stage V ♂, 2.45 mm. This specimen and those recorded from the west coast of Ireland as *G. affinis* and *G. brevispinus* (Farran, 1905, 1918) are almost certainly the same as the form which With (1915) calls "*G. brevispinus*?". With is inclined to regard *G. major* Wolfenden, *G. brevispinus* G. O. Sars, and *G. affinis* G. O. Sars as being all the same species, and justly points out that, should *G. major* and *G. affinis* prove to be identical and separate from *G. brevispinus*, Wolfenden's name is the earlier.

**GAIDIUS MINUTUS G. O. Sars.**

*Distribution*.—1000–750 fathoms, one specimen, ♀.

Length, ♀, 2.95 mm., cephalothorax 2.36 mm., abdomen .58 mm. The length of Sars's type was 2.5 mm. This species is easily recognized by its stout rostrum, short abdomen with swollen genital segment, and thoracic spines reduced to minute nodules. The maxillipede has no basal lamella, and the exopodite of the 1st foot has two *se*. There is a group of acicular spines on the *B* 2 of the 4th foot.

**GAETANUS MAJOR Wolfenden.**

*Distribution*.—

At 350 fms. in 1 out of 1 haul, with .22 per cent.

Between 400–300 fms. in 1 out of 3 hauls, with	.7	} Average specimens per 100-fathom haul.
500–400	3      3	
750–500	4      4	

The range is from 350 fathoms to below 500, with an optimum at 400–500 fathoms.

Length, ♀, 4.45–4.8 mm.

The arguments for the identity of *Gaetanus Kruppi* and *G. major* seem very strong, but I have retained the name *G. major* which has been generally used for the Atlantic form, while admitting the identity of these specimens with those doubtfully referred to *G. Kruppi* by With (1915), who has summarised the arguments for and against his opinion. If, however, it can be shown that the absence of a lamella on the 1st basal joint and the 2nd maxillipede is, as Wolfenden states, a genuine character of *G. major*, the use of that name for the common Atlantic form, which possesses such a structure, cannot be justified.

## GAETANUS MINOR Farran.

*Distribution.*—

By day in				By night in			
At 50 fms.	0 out of 7 hauls.			1 out of 5 hauls (1 specimen).			
75	0	3		4	8 hauls, with .1	} % of aver. haul.	
100	1	12	(1 specimen).	5	9		
At 150 fms.	in 0 out of 1 haul, with 0						
200	1	2	.4	} Per cent. of average haul.			
250	2	2	1.3				
300	1	1	.25				
350	1	1	.52				
Between 150- 50 fms.	in 0 out of 1 haul, with 0						
200-100	4	6	1.7	} Average specimens per 100-fathom haul.			
250-150	3	3	5				
300-200	1	3	.7				
400-300	0	3	0				
500-400	1	3 (1 specimen)					
750-500	1	4 (1 specimen)					
1000-750	1	3 hauls, with .7					

The optimum, by day at any rate, and possibly the normal range lies at about 150-250 fathoms. There is distinct evidence that a few specimens ascend into the lower 50 fathoms of the epiplankton by night (in 10 out of 22 hauls), from which they are practically absent by day (in one out of 22 hauls).

Length, ♂, 2.34-2.4 mm.

The specimens recorded by Wolfenden (1911) and With (1915) are, I have no doubt, identical with mine.

## GAETANUS PILEATUS Farran.

*Distribution.*—

At 200 fathoms in	1 out of 2 hauls, with .75			} Per cent. of average haul.	
250	1	2	.2		
300	1	1	.37		
350	1	1 haul (1 specimen).			
Between 200-100 fms.	in 2 out of 6 hauls, with .5			} Average specimens per 100-fathom haul.	
250-150	3	3	2.7		
300-200	2	3	1.3		
400-300	0	3	0		
500-400	1	3 (1 specimen)			
750-500	0	4 hauls, with 0			
1000-750	1	3	.27		

The maximum seems to be between 300 and 150 fathoms, the range extending in very small numbers down to below 750 fathoms. Thus it seems to inhabit much lesser depths in this region than *G. major*, though off the west coast of Ireland, as I have found, and farther north, as With's records (1915) show, both species usually occur together.

Length, ♀, 5.3-5.4 mm.

**GAETANUS MILES** Giesbrecht.

*Distribution.*—One mature female and eight immature specimens, stages IV, III, and II, were taken on Station 36 in the horizontal net at 150 fathoms, and two immature specimens, stages IV and II, in the horizontal net at 200 on the same station. Possibly a patch of southern water was encountered on this station. This species was taken once by the 'Thor' in the same neighbourhood, one specimen with net on 300 m. of wire in 48° 09' N., 8° 30' W., and also on three stations farther north, as far as 61° 34' N. (With, 1915). It was also taken on four occasions off the west coast of Ireland (Farran, 1908). It is evidently not a normal inhabitant of the deep water of the N.E. Atlantic, but is probably drifted northwards in small numbers at moderate depths.

Length, ♀, 4.25 mm., antennules 10.58 mm.; stage IV, 2.76 mm., antennules 7.1 mm.; stage III, 2.22 mm., antennules 5.46 mm.

The jointing in the antennules of the female shows some, but not all, of the differences from Giesbrecht's description noticed by With in his Atlantic specimens, viz. segment 13 is very little longer than 8-9 and 1.2 times as long as 24-25, and segment 19 is shorter than 22 but longer than 20.

**GAETANUS LATIFRONS** G. O. Sars.

*Gaetanus Holti* Farran.

*Distribution.*—

At 350 fms. in 1 out of 1 haul, with .16 per cent.

Between 400-300 fms. in 2 out of 3 hauls, with 1.0	Specimens
500-400                    1            3            (1 spec.)	} per 100-
750-500                    3            4 hauls, with .6	
	fathom haul.

The numbers are so small that the extent of the range is uncertain. It reaches at any rate from 350 to below 500 fathoms.

Length, ♀, 4.8 mm.

**EUCHIRELLA ROSTRATA** Claus.

*Distribution.*—Only found in the horizontal nets at 300 fathoms, 1 specimen stage IV, and 350 fathoms, 2 specimens stage V, on Station 36. It is evidently not a regular frequenter of this area, although it has been taken abundantly by the 'Thor' about fifty miles farther north.

Length, stage V ♂, 2.14-2.32 mm.

**EUCHIRELLA CURTICAUDA** Giesbrecht.*Distribution.*—

By day in				By night in			
At 0 fms.	2 out of 3 hauls, with .04		Per	1 out of 4 hauls (1 spec.)		Per	
25	0            6	0	cent.	3            6	with .62	cent.	
50	0            7	0	of	4            5	1.1	of	
75	1            3	.19	aver.	8            8	1	aver.	
100	12          12	1.1	haul.	9            9	1.2	haul.	

At 150 fms. in 1 out of 1 haul, with .7				
200	2	2	1.3	} Per cent. of average haul.
250	2	2	.4	
300	1	1	.37	
350	1	1	1.1	

Between 150- 50 fms. in 1 out of 1 haul, with 9				
200-100	4	6	5	} Average specimens per 100-fathom haul.
250-150	2	3	2	
300-200	2	3	2	
400-300	3	3	5.3	
500-400	2	3	.7	
750-500	2	4	.2	
1000-750	1	3	.4	

Present at 100 fathoms by day and night. Absent above that depth during the day, except for a few stray specimens, but rising to 25 fathoms during the night in moderate numbers, more than one per cent. of the catch. Below 100 fathoms it is regularly present down to 400 fathoms and, in much smaller numbers, down to 750 and 1000 fathoms. The great majority of the specimens taken were immature, and a few males occurred at various depths.

This vertical distribution agrees fairly well with that recorded by With (1915) from more northern latitudes and also with my records from the west coast of Ireland.

Length, ♀, 4.42-4.6 mm.; ♂, 3.9-4.14 mm.; stage V ♀, 3.34-3.43 mm.; stage V ♂, 3.46-3.52 mm.

#### *EUCHIRELLA MESSINENSIS* (Claus).

##### *Distribution.*—

Absent by day from 0 to 100 fathoms, 37 horizontal hauls.

By night at 0 fms. in 0 out of 4 hauls.

25	3	6 hauls, with .05	} Per cent. of average haul.
50	3	5	
75	5	8	
100	5	9	

Absent from 7 horizontal hauls between 150 and 350 fathoms.

Between 400-300 fms. in 1 out of 3 hauls (one specimen, ♀).

The records suggest that it is present by day below 100 fathoms in very small numbers and rises into the upper epiplankton by night.

Length, ♀, 5.35-6.2 mm.; ♂, 4.74-4.98 mm.; stage V ♀, 3.9-4.32 mm.; stage V ♂, 3.78-4.17 mm.; stage IV ♀, 2.92-3.12 mm.; stage IV ♂, 3.18 mm.; stage III, 2.34-2.36 mm.

The first foot of the male agrees with With's figure (1915), differing from that of the female in the absence of *se* 1 and *re* and the reduction of *se* 2 to a very small spine. The jointing between *re* 1 and *re* 2 is distinctly indicated, but not complete.

## EUCHIRELLA BITUMIDA With.

*Euchirella galeata* Farran, 1903.

*Distribution*.—At 75 fathoms in 2 out of 8 hauls by night, 2 specimens, ♀, and at 100 fathoms in one out of 9 hauls by night, one ♀. Not taken in horizontal or vertical hauls below 100 fathoms. With's specimens were taken at considerable depths, and specimens from the west coast of Ireland, recorded in error as *E. galeata*, at 350 to 700 fathoms.

Length, ♀, 6·7 mm.

This species is the Atlantic representative of the Pacific form described by Giesbrecht as *E. galeata*, with which I formerly identified it. I believe, however, that With (1915) is right in separating the two species, as the genital segment of *E. galeata*, as figured by Giesbrecht and Esterly, is in lateral view very much wider posteriorly than anteriorly, whereas in *E. bitumida* the widest part is near the anterior end.

## UNDRUCHÆTA MINOR, Giesbrecht.

*Distribution*.—

By day in				By night in			
At 0 fms.	0 out of 9 hauls.			2 out of 4 hauls, with	·83	Per	
25	1	6 hauls, with	·03	3	6	1·1	cent.
50	0	7	0	5	5	6	of
75	1	3	·02	8	8	2	average
100	3	12	·04	9	9	3·7	haul.
At 150 fms. in 1 out of 1 haul (1 specimen).							
200	1	2 hauls, with	1·5	} Per cent. of average haul.			
250	2	2	3·3				
300	1	1	1·4				
350	1	1	2·0				
Between 150– 50 fms. in 0 out of 1 haul, with 0							
200–100	4	6	4·5	} Average specimens per 100-fathom haul.			
250–150	3	3	23·3				
300–200	3	3	18·3				
400–300	3	3	8·7				
500–400	3	3	2·0				
750–500	3	4	1·8				
1000–750	2	3	1·3				

Very scarce above 200 fathoms in daylight. By night it rises into the epiplankton, forming 6 per cent. of the catch at 50 fathoms or, taking an average of the catches at 50, 75, and 100 fathoms, 3·9 per cent. Horizontal hauls show a day maximum at 250 fathoms, and these are supported by the vertical hauls from 250 to 150 fathoms, which give the high average of over 23 specimens per 100-fathom haul.

The proportion of young stages in all gatherings was high. The percentages for a few hauls are given below. The daylight hauls in the upper mesoplankton, all taken at the same time, show, after making allowance

for differences of mesh, that the main body of mature females was at a lower level on that occasion than most of the younger stages, and the epiplankton night hauls indicate that all stages participate in the upward migration. Mature males were very rarely met with.

Station No.	Depth in fms.	Mesh.	♀.	V.	IV.	III.	II.	
33f . . . .	50	60	25	16	59	—	—	} Night hauls.
36d . . . . .	50	60	8	5	13	79	—	
36g . . . . .	200	45	—	—	3	89	6	} Daylight hauls.
36i . . . . .	250	60	—	—	58	42	—	
36k . . . . .	300	45	5	07	14	9	5	
36l . . . . .	350	36	30	22	7	41	—	

Length, ♀, 3·95–4·25 mm.; ♂, 3·42–3·9 mm.

### UNDEUCHÆTA MAJOR Giesbrecht.

#### *Distribution.*—

By day in		By night in		Per cent. of aver. haul.
At	0 fms.	0 out of 4 hauls, with 0		
25	} 0 out of 25 hauls.	3	6	·1
50		4	5	·06
75		5	8	·03
100	1 out of 12 hauls (1 spec. dead).	6	9	·07
At 150 fms.	} in 0 out of 5 hauls.			
200				
250				
300	in 1 out of 1 haul (1 specimen).			
350	1	1	(2 specimens).	
Between 400–300 fms. in 1 out of 3 hauls, with ·7		} Per 100-		
750–500		1	4	·2
		} fathom haul.		

The regular occurrence in the epiplankton by night, though in very small numbers, and the absence by day is evidence for a diurnal oscillation, but where the species is to be found by day is not clear from the records. It seems probable that it descends below 250 fathoms.

This species is evidently an exclusively southern form, as With (1915) does not record it from the extensive 'Ingolf' collections, and in the 'Thor' collections he found it only on three stations, between 47° 47' N. and 51° 00 N.

Length, ♀, 4·8 mm.; ♂, 4·26–4·74 mm.

### CHIRUNDINA STREETSII, Giesbr.

#### *Distribution.*—Absent from the surface.

By day in		By night in		Per cent. of average haul.
At	25 fms.	2 out of 6 hauls, with ·01		
50	} 0 out of 28 hauls.	3	5	·05
75		2	8	·01
100		4	9	·04



At 300 fms. in 1 out of 1 haul, with	·12	} Per cent. of average haul.
350                    1                    1	·86	

Between 200-100 in 1 out of 6 hauls	} 1 specimen in each haul.
400-300                    1                    3	
500-400                    1                    3	

Though much scarcer than *Undeuchæta major* this species resembles it in vertical distribution, showing a distinct upward movement by night from depths below 200 fathoms.

Length, ♀, 5·2 mm.; ♂, 4·2 mm.

#### CHIRUNDINA PARVISFINA (Farran).

*Gaidius parvispinus* Farran, 1908.

One specimen, stage IV ♂, was taken on Station 22*b* in a vertical net from 750 to 500 fathoms.

Length of stage IV, 3·12 mm. With's (1915) specimen of this stage measured 3·46 mm. His discovery of the male justifies the separation of this species from the genus *Gaidius*.

#### EUCHÆTA GRACILIS G. O. Sars.

*Euchæta quadrata* Farran, 1908.

#### Distribution.—

By day in				By night in				} Per cent. of average haul.
At 0 fms.	0 out of 22 hauls.			0 out of 6 hauls, with 0				
25				3	6	·41		
50				5	5	·39		
75	1 out of 3 hauls (1 specimen).			7	8	·54		
100	2	12 hauls, with ·17 %.		7	9	·4		
At 150 fms. in 1 out of 1 haul (1 specimen)								} Per cent. of average haul.
200	1	2 hauls, with ·13						
250	2	·62						
300	0	0						
350	1	·59						
Between 150- 50 fms. in 0 out of 1 haul.								} Average specimens per 100-fathom haul.
200-100	0	6						
250-150	0	3						
300-200	2	3 hauls, with 2						
400-300	2	3		2·7				
500-400	2	3		1				
750-500	3	4		·8				
1000-750	1	3		·27				

In addition two specimens were taken in one out of three surface hauls by night with the fine (180) meshed net. Between 750 and 2000 fathoms young stages of large *Euchætas*, probably not *E. gracilis*, occurred frequently.

The numbers of specimens are not large enough to determine the range with any certainty. It evidently extends to below 750 fathoms and by day centres about 250-400 fathoms, rising during the night in small numbers into the epiplankton as far as the surface.

Mature specimens, both male and female, were taken in considerable numbers at all levels in the epiplankton by night, but by day mature examples were only found at 350 fathoms in the horizontal nets and between 300 and 750 fathoms in the vertical nets. This seems to show that the diurnal movements of the adults are much more definite than those of the younger stages.

Length, ♀, 6·8–6·84 mm., ♂, 5·5–6·5 mm.; stage V ♀, 4·8 mm., V ♂, 4·8 mm.

The identification of immature specimens of *Euchæta* cannot be regarded as quite certain, as the number of species to which they might possibly be referred is large. In this case, however, *E. gracilis* was the only available adult which occurred at the depths in question, and it is probable that most if not all the young stages which cannot be referred to *E. acuta* belong to it. All specimens of stages IV and V which have been recorded as *E. gracilis* had acute lateral corners to the 5th thoracic segments.

#### *EUCHÆTA BARBATA* Brady.

*Euchæta barbata* Farran, 1908.

*Euchæta barbata* With, 1915.

*Distribution*.—In two vertical hauls between 1000 and 750 fathoms. (31 d) 1 ♀; (32 k) 2 ♀, 1 stage V ♀.

Length, ♀, 7·5 mm. The bright red colour of the thoracic appendages is still retained after more than twenty years' preservation in formalin. I use the name of *E. barbata* for the form with a small tubercle on the left side of the genital segment. The only previous records for the species as thus restricted are from off the west coast of Ireland (Farran, 1908) and between 61° 30' N. and 61° 34' N. in the East Atlantic (With, 1915). Amongst the known North Atlantic species this form agrees most nearly with Brady's description (1883) of his South Atlantic species, but until it is actually taken in the same locality it is not possible to be certain that the identification is correct.

#### *EUCHÆTA SPINOSA* Giesbr.

One specimen, ♀, in horizontal net at 25 fathoms, by night. Station 36 c. Length, ♀, 6·9 mm.

Evidently a southern or Mediterranean species at the extreme northern extension of its range, occurring, as might be expected, in the epiplankton.

#### *EUCHÆTA ACUTA* Giesbr.

##### *Distribution*.—

By day in				By night in			
At	0 fms.	2 out of 9 hauls, with	·12	1 out of 4 hauls, with	·25	Per	
25	1	6	(1 spec.)	4	6	·5	Per
50	1	7	(1 „)	5	5	·7	cent.
75	2	3 hauls, with	·18	8	8	·7	of
100	12	12	·22	9	9	1·5	aver.
			haul.				haul.

At 150 fms. in 1 out of 1 haul, with 3.2				} Per cent. of average haul.
200	2	2	1.8	
250	2	2	.4	
300	1	1	.37	
350	1	1	1.1	

Between 150- 50 fms. in 1 out of 1 haul, with 21				} Average specimens per 100-fathom haul.
150-100	1	1	14	
200-100	6	6	13	
250-150	3	3	4.3	
300-200	2	3	2.3	
400-300	1	3	.3	
500-400	0	3	0	
750-500	0	4	0	
1000-750	2	3	.4	

The nocturnal upward movement is well marked in the upper seventy-five fathoms of the epiplankton, the day optimum extending clearly from 100 to 200 fathoms. From this optimum the numbers rapidly diminish down to 300 fathoms, below which only stragglers are met with. This is by far the commonest species of *Eucheta* in the collection. Most of the specimens were immature.

Length, ♀, 4.1-4.15 mm. ; ♂, 3.6-3.72 mm.

#### Genus SCAPHOCALANUS.

This genus, of which the type is *S. magnus* T. Scott, comprises, in the sense in which it is here used, a group of species characterized by an elongate, rather secondary form, antennules broad and compressed in the proximal half, antennæ with *ri* almost as long as *re*, first feet without a spine on the 1st joint of the exopodite, and fifth feet 1- or 2-jointed, with an elongated terminal joint having a long slender inner edge seta and a shorter terminal seta or slender spine. With this extension it would include *S. magnus* T. Scott, *S. brevicornis* Sars, *S. sub-brevicornis* Wolf., *S. echinatus* Farran, *S. impar* Wolf., *S. gracilis* Wolf., *S. elegans* Wolf., *S. major* T. Scott, *S. elongatus* A. Scott, *S. longifurca* Giesbr. Only three of these species are included in the present collection.

#### SCAPHOCALANUS MAGNUS T. Scott.

##### *Distribution.*—

Between 300-200 fms. in 2 out of 3 hauls (2 specimens).  
500-400 1 3 (1 specimen).

At 350 fms. in 1 out of 1 haul, with .5 per cent. of the total haul, or more briefly: between 200 and 500 fathoms, scarce.

Two mature females were taken at 350 fathoms, the remaining specimens being in stage V.

Length, ♀, 4.56 mm. ; stage V, 3.6-3.8 mm.

This species is, as Wolfenden (1911) has remarked, one of the most widely distributed of pelagic copepods, having been recorded from the Arctic and Antarctic regions, the north, south, and tropical Atlantic, and the Pacific oceans.

*SCAPHOCALANUS ECHINATUS* Farran.

*Distribution.*—

By day in				By night in			
At 0 fms.				1 out of 4 hauls, with	.1		
25	} 0 out of 37 hauls.			3	6	.02	} Per cent. of average haul.
50				4	5	.32	
75				6	8	.47	
100				9	9	.29	
At 150 fms. in	0 out of 1 haul, with 0			} Per cent. of average haul.			
200	1	2	1.0				
250	2	2	.34				
300	1	1	.37				
350	1	1	.52				
Between 150– 50 fms. in	0 out of 1 haul, with 0			} Average specimens per 100-fathom haul.			
200–100	0	6	0				
250–150	2	3	3				
300–200	2	3	3.7				
400–300	1	3	.3				
500–400	1	3	1.3				
750–500	2	4	.1				
1000–750	1	3	1.0				

The range by day is from 200 fathoms downwards to below 750, the upward limit being clearly marked and the optimum lying between 200 and 300 fathoms. By night there is a well-marked migration into the epiplankton, occasional specimens reaching the surface.

Length, ♀, 1.8–2.4 mm.

*SCAPHOCALANUS BREVICORNIS* G. O. Sars.

*Scaphocalanus gracilipes* Farran, 1908.

*Distribution.*—

Between 200–100 fms. in	1 out of 6 hauls, with		.5	} Average specimens per 100- fathom haul.
500–150	0	12	0	
750–500	3	4	.7	
1000–750	1	3	.53	

The few specimens which were taken are not sufficient to give a clear view of the vertical range. It seems to be similar to that of *S. echinatus*, except that it is proportionately more plentiful in the lower layers.

Length, ♀, 2.0–2.6 mm.

I think With (1915) is correct in putting *S. gracilipes*, the name which I formerly gave to this species, as a synonym of *S. brevicornis*. I have since found specimens in which the 5th feet were of the type figured by Sars (1900), the outer edge tooth being situated opposite to the inner edge seta, and also one specimen in which the left 5th foot had a rudimentary endopodite and the right 5th foot was absent.

*SCOLECITHRICELLA DENTATA* (Giesbr.).*Distribution.*—

Depth.	By day in				By night in			
0 fms.	2 out of 9 hauls, with	.1	Per		1 out of 4 hauls, with	.1	Per	
25	0	6	0	cent.	4	6	.7	cent.
50	1	7	(1 spec.)	of	5	5	1.9	of
75	2	3 hauls, with	.1	average	8	8	1.3	average
100	7	12	1.5	haul.	9	9	1.8	haul.
At 150 fms. in 1 out of 1 haul, with	1.6							
200	2	2	4.6	} Per cent. of average haul.				
250	2	2	1.8					
300	1	1	1.2					
350	1	1	1.5					
Between 150–50 fms. in 1 out of 1 haul, with	5							
200–100	6	6	6.3	} Average specimens per 100-fathom haul.				
250–150	3	3	9					
300–200	1	3	3					
400–300	3	3	2.7					
500–400	1	3	2					

Not below 500 fathoms, except for one dead specimen between 1250–1000 fathoms.

The day maximum lies at about 200 fathoms with a downward range to 500 fathoms and occasional specimens above 100 fathoms. The numbers in the epiplankton show a distinct increase by night below 25 fathoms, with occasional specimens between that depth and the surface.

Length, ♀, 1.5–1.6 mm.

*SCOLECITHRICELLA VITTATA* (Giesbr.).

*Distribution.*—One specimen in a horizontal net at 100 fathoms and another in a vertical haul between 750–500 fathoms; both females.

Length, ♀, 1.5–1.7 mm.

Genus *SCOLECITHRIX*.

I have included in this genus all the species of the *Scolecithricidae* which have not been allotted to separate genera or of which the allotment is questionable, although it is evident that this grouping is indefensible except, on the grounds of convenience, as a temporary measure.

*SCOLECITHRIX CURTA*, sp. n. (Pl. 7. figs. 1–6.)

*Description.*—Female, length 1.06–1.3 mm. Body (Pl. 7. figs. 1, 2) of the same general form as in *Scaphocalanus brevicornis*. In a specimen of 1.14 mm. the united cephalon and 1st thoracic segment measure .6 mm., the remaining thoracic segments to base of abdomen .26 mm., abdomen .28 mm.; 5th thoracic segment produced into a blunt point; 4th and 5th thoracic segments fused. Abdomen slender, genital segment scarcely wider than the following segments, without genital boss. Proportional length of abdominal segments and furca 18 : 12 : 12 : 7 : 11.

Rostrum of two slender filaments. Antennules not reaching the end of the cephalothorax. Proportional length of antennular joints in  $\cdot 01$  mm.:—

No.: 1 2 3 4 5 6 7 8-10 11 12 13 14 15 16 17 18 19 20 21 22 23 24-25

Size: 6 8 3 2.5 2.5 2.3 2.3 6 1.5 2.0 2.4 2.6 2.4 2.7 2.7 2.7 3 2 2.6 2.4 3.6 5.5 = .707 mm.

A transparent lamina, as in *Scaphocalanus*, runs along the posterior margin of the antennule from joints 1 to 21 inclusive. Antennæ with *ri* about  $1\frac{1}{4}$  times as long as *re* and much thicker. Mandibles, maxillæ, and maxillipedes as in *Scaphocalanus magnus*.

Swimming feet in general form, jointing and number of setæ as in *Scaphocalanus magnus*, with the exceptions that in the 1st foot (Pl. 7. fig. 3) the *re* has no *se*, and the *ri* has no distinct shoulder on its outer margin and has 2 *st* and 2 *si*. In one specimen, however, measuring 1.3 mm., the *ri* of the 1st foot has the normal number of setæ, viz. 2 *st* and 3 *si*, and also a faintly indicated shoulder on the outer margin (Pl. 7. fig. 4). There is no spinulation on the faces of the *re* of the 2nd to 4th feet, but the *ri* of the 2nd foot (Pl. 7. fig. 5) has four small spinules on the 2nd joint and the *ri* of the 3rd foot (Pl. 7. fig. 6) three spinules on the 2nd joint and one on the 3rd joint. Serration of *st* of *re* of 2nd and 3rd feet moderately coarse and very oblique, about 15 serrations on each spine. The 4th foot was broken in all specimens which I have seen. The figures and descriptions of the 2nd and 3rd feet are taken from a specimen taken off the west coast of Ireland, as these feet were imperfect in all the 'Research' specimens. 5th feet absent.

Except for the absence of the 5th feet this species might have been included in the genus *Scaphocalanus*, to which it is much more closely allied than to the other species of *Scolecithrix* which have no 5th feet, and it is probable that it will ultimately find a place in or next to that genus.

*Distribution.*—

Horizontal nets at 200 fms. (2 specimens), and 350 fms. (1 specimen).

Vertical net, 250-150 fms. (1 specimen), 1000-750 fms. (2 specimens).

A specimen was also found in a horizontal net at 630 fathoms, fished off the west coast of Ireland in 1905.

*SCOLECITHRIX AUROPECTEN* Giesbr.

*Distribution.*—

Horizontal nets at 250 and 350 fms. (1 specimen in each).

Vertical net, 1000-750 fms. (1 specimen).

Length, ♀, specimens from 250 and 350 fms., 2.0-2.04 mm.; specimen from 1000-750 fms., 1.04 mm.

The two larger specimens, though slightly larger than the type, which measured 1.8 mm., agreed well with Giesbrecht's description. The smaller specimen differs in having no *se* on *re* 1 of the 1st foot; possibly it may have been broken off, but there is no indication of this, and the 5th feet are of a slightly different shape, the terminal joint being a little narrower proximally

than distally and having a faintly indicated segmentation dividing it into two equal parts. These differences occurring in a single specimen do not justify the description of a new species, as they may be within the limits of normal variation.

*S. auropecten* has already been recorded from the North Atlantic by I. C. Thompson.

*SCOLECITHRIX FOWLERI*, sp. n. (Pl. 7. figs. 7-12; Pl. 8. figs. 1-3.)

*Description.*—Length, ♀, 2.04 mm.; cephalothorax 1.56 mm.; abdomen .48 mm. Body (Pl. 7. figs. 7, 8) oval, slightly tapered anteriorly in dorsal view; abdomen slender, genital segment slightly swollen beneath, lengths of abdominal segments in dorsal view in the proportion 18 : 10 : 8 : 6; furcal rami about as wide as long and equal to the anal segment in dorsal view. The only specimen was in rather bad condition, and it is possible that the shape of the cephalothorax may not be figured quite correctly and also that some of the setæ on the appendages may have been broken off without leaving a trace. Rostrum long and slender, consisting of a narrow flattened plate tapered to a fine point and with a median groove from the base to the apex. Cephalon and *Th* 1 and *Th* 4 and 5 fused. Antennules (Pl. 7. fig. 9) very short, not reaching to *Th* 3, 16-jointed, the original joints 7-12, 20-22, and 23-24 being fused; original joints 3-12 are broad, with a thin crest-like serrated anterior margin. Setæ mostly broken off. Antennæ (Pl. 7. fig. 10) of normal forms with *ri* slightly longer and much thicker than *re*. Mandibles with both rami about equal and cutting edge with four strong teeth. 1st maxillæ (Pl. 7. fig. 11) with *li* 1 of normal size, with nine, or more, stout spines, *li* 2 and *li* 3 absent, *le* 1 enlarged, with seven long densely plumose setæ and two small setæ, *ri* and *re* much reduced, the former with 2, the latter with 3 setæ. 2nd maxillæ with the usual 5 lobes, lobes 1 to 3 each with a pair of setæ, lobe 4 with two strong setæ and one slender, lobe 5 produced without visible articulation into a single strong seta. The setæ on lobe 1 and the proximal setæ on lobe 2 are small and lightly feathered; the remaining setæ are large and subequal, and each is furnished with a double row of strong close-set serrations. The terminal joints, *ri*, have been broken off on both right and left 2nd maxillæ, but if I am right in believing this species to be one of the Scolethricidæ, they were probably furnished with vermiform or amallæ-bearing setæ. Maxillipedes (Pl. 7. fig. 12) with the first joint equal to the second and third together, the fourth joint distinctly shorter and narrower than the third, and the three succeeding joints gradually decreasing in size. The setæ on the maxillipedes are scanty and comparatively short. The first joint has a long and a short distal seta, the second joint a short median seta and a longer terminal one. The remaining joints have about 3 setæ each, the longest being about equal to the length of the first joint.

The swimming feet have in general the jointing, setæ, and spines which are found normally in *Scolecithrix*. The 1st foot has, however, no *se* on *re* 1, and no *si* on *b* 2. The *se* on *re* 2 reaches nearly to the end of the next joint, and on *re* 3 there is a strong tooth separating the *se* and the *st*. *P* 2 (Pl. 8. fig. 1) has on *ri* 2 two groups of three or four slender spines, the proximal group set obliquely on the face of the joint, the distal group in a transverse row. *re* 2 has a transverse row of small spinules, and *re* 3 two curved transverse rows of similar spinules. *P* 3 (Pl. 8. fig. 2) has two transverse groups of slender spinules on *ri* 3 and an oblique group on *ri* 2; *re* 2 has a distal row, as in *P* 2, and *re* 3 three transverse rows of very fine spinules, one distal, one median, and one proximal. *P* 4 has spinulation of *ri* 3 similar to *P* 3; *ri* 2 has two groups of long acicular spinules; *re* 2 has a few very fine spinules distally near the outer edge of the joint, and *re* 3 has only one median transverse row of very minute spinules. The terminal spines of the 2nd and 4th swimming feet have about 21 and 24 slender serrations respectively, each serration about as long as the thickness of the spine at the point of origin of the serration; the serrations are much more oblique and closely set on the 4th foot than on the 2nd. The terminal spines of *P* 3 were missing. No *si* was found on *b* 1 of *P* 3 and 4; probably the 5th feet (Pl. 8. fig. 3) are symmetrical, each consisting of a short terminal club-shaped joint arising from a much shorter basal joint; the second joint has a minute terminal spine and a long curved spine arising near the distal end of the inner margin.

This species is characterized chiefly by the form of the rostrum, the short antennules, the great reduction of the outer and inner rami of the 1st maxilla, and the elongated and plumose setæ of the outer lobe of the same appendage. It does not seem to fall into line with any of the described species of *Scolecithrix*.

*Distribution*.—One specimen was taken by day in a horizontal tow-net at 100 fathoms (30 g).

*SCOLECITHRIX FALCIFER*, sp. n. (Pl. 8. figs. 9-14.)

*Description*.—Length, ♀, 2.0 mm. Cephalothorax (Pl. 8. fig. 9) oval in dorsal view, about  $2\frac{1}{4}$  times as long as wide. Abdomen (Pl. 8. fig. 10) about one-fifth of the total length, genital segment not swollen ventrally, anal segment very short. Antennules reaching to the beginning of the genital segment. Length of joints in .01 mm.:—

No.: 1 2 3 4 5 6 7 8-9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24-25  
Size: 12 8 5 5 5.5 5 5 9 8.5 8.5 4 6 7 8 10 10 10 9 13 13.5 9 13 18

Two setæ on both 14th and 18th joints. Antennæ (Pl. 8. fig. 11) with *re* a little longer than *ri*; the 1st joint of *ri* thicker than the 2nd joint of *re* and thinner than the terminal joint of *re*. Mandible with *re* a little larger than *ri*. 1st maxilla not examined. 2nd maxilla with slender setæ on all its five lobes. The number of amalliform terminal setæ could not be made out, but some were certainly present. Maxillipede as in *S. globiceps* and



*S. robusta*, with a well-marked smalliform seta on the 1st joint. 1st foot with *se* on all joints of *re*; the *se* on *re* 2 is not quite half as long as *re* 3; *se* on *re* 1 as long as *re* 2. 2nd foot (Pl. 8. fig. 12) *se* of *re* 1 long and curved, nearly as long as the joint; *re* 2 with a patch of spinules and a distal transverse row of larger spinules on the lower face; *re* 3 with two groups of spinules and a proximal patch of smaller spinules on the lower face; the upper faces of *re* 2 and 3 are covered with fine asperities; *ri* 2 with three transverse patches of spinules, the median patch much the most slender. 3rd foot (Pl. 8. fig. 13) with spinules on lower face of *re* as in 2nd foot; *ri* 2 with two small transverse rows, and *ri* 3 with a small proximal group and a transverse row of larger spinules; *b* 2 with a group of slender spinules at the base of *re*; *b* 1 with a group of minute asperities on the centre of the outer margin as in *S. globiceps*; 4th foot *re* without spinules on lower face except for a fine transverse distal row on *re* 2; *ri* with a longitudinal band of fine spinules on the lower face; *bi* with a very small inner edge seta and a few small asperities on the centre of both inner and outer margins. The terminal spines of the 2nd, 3rd, and 4th feet have respectively 45, 60, and 52 teeth, counting the most minute, the teeth being slender and close-set, but separate, and not very oblique. 5th feet (Pl. 8. fig. 14) one-jointed with a slight median constriction, a stout inner edge spine with minute serrations, a somewhat small terminal spine, and a distal tooth on the outer margin.

The curved outer edge spine on *re* 1 of the 2nd foot is also found in *Scolecithricella dentata*, *S. vittata*, and others of that genus, as well as in *Scolecithrix globiceps*, and possibly indicates affinity with the former genus.

*Distribution*.—One specimen in a vertical haul (22 b), 750–500 fathoms.

*SCOLECITHRIX VALENS*, sp. n. (Pl. 8. fig. 4.)

*Description*.—Length, ♀, 2.4 mm.; cephalothorax 1.86 mm.; abdomen .54 mm. Form of body almost exactly as in *S. valida*, with no trace of emargination in the lateral aspect of the 5th thoracic segment. Appendages much damaged, but, as far as they are present, they agree closely with those of *S. valida*. Terminal joints of swimming feet missing. 5th feet (Pl. 8. fig. 4) with a short basal joint and a terminal joint about  $2\frac{1}{2}$  times as long as the basal, with a short terminal spine near the inner edge, an inner edge spine about  $\frac{2}{3}$  times as long as the joint, and a minute outer edge tooth opposite to the base of the inner edge spine. The 5th feet, while resembling those of *S. valida* in general form, differ in being of equal width throughout, those of *S. valida* being distinctly clavate. A specimen taken off the west coast of Ireland in 1905, identical with the above, measured 2.5 mm. It retained 14 joints of the antennules, which measured, in .01 mm.:—

No. ....	1	2	3	4	5	6	7	8-9	10	11	12	13	14
Size ....	13	16	7	7	7	7	6	13	5	6	6	9	11

The 14th joint bore two setæ, as in *S. valida*.

Though I have given a separate name to this species, it is really nothing but a small form of *S. valida*, from which it differs only in size, 2.4–2.5 mm. instead of 3.8–3.95 mm., and in having less clavate 5th feet. Although the terminal spines of the swimming feet are missing, I think that they will probably be found to agree with those of *S. valida*, which has about 35 partially fused serrations on the *st.* *S. robusta*, which has 5th feet somewhat resembling *S. valens*, can be separated from *S. valida* and, if my surmise is correct, from *S. valens* by the large number, ca. 50, of fine serrations on the *st* of its swimming feet.

*Distribution.*—Vertical net, 750–500 fms. (2 specimens, ♀).

One specimen, as mentioned above, was taken during the Irish fishery investigations in 1905 off the west coast of Ireland, in a horizontal net at 700 fathoms.

#### SCOLECITHRIX EMARGINATA Farran.

*Scolecithrix obtusifrons* Farran, 1908 (*nec* Sars).

*Scolecithrix emarginata* Sars, 1924.

*Distribution.*—Vertical net, 500–400 fms. (1 ♀).

Length, ♀, 3.96 mm. This is slightly smaller than the recorded size, 4.3–5.6 mm., but the specimen does not differ in other respects.

Sars's recently published figures have made it clear that he rightly regards *S. emarginata* as distinct from *S. obtusifrons*, with which I identified it in 1908. I have therefore again used the name by which I originally described the species.

#### SCOLECITHRIX OVATA Farran.

*Distribution.*—

Depth.	By day in			By night in			Per cent. of average haul.
0 fms. } 25 } 50 } 75 }	0 out of 24 hauls.			1 out of 4 hauls, with 4 6 4 5 6 8	.05 .15 .33 .14		
100	5 out of 12 hauls, with .1			{ Per cent. of aver. haul.	7 9	.26	
At 150 fms. in 1 out of 1 haul, with .18							
200	1	2	.1	{ Per cent. of average haul.			
250	2	2	.5				
300	1	1	.47				
350	1	1	.3				
Between 150- 50 in 0 out of 1 haul.							
200-100	0	6	{ 3 hauls, with 1.3 } Average specimens per 100-fathom haul.				
250-150	1	3					
300-200	2	3					1.0
400-300	2	3					.7
500-400	1	3					.7
750-500	1	4	.1				
1000-750	2	3	.7				

Absent by day from 75 fathoms to the surface, but coming up in small numbers by night. The day maximum lies at about 200–300 fathoms.

Length, ♀, 2·08–2·13 mm. This species has been put by most writers, including myself, in the genus *Scolecithricella*, but I do not think that this arrangement can be justified, as, except for its 5th feet. *S. ovata* is much more closely related to *S. robusta* than to *Scolecithricella minor*, the type of the genus *Scolecithricella*. The possibly generic characters possessed by *S. robusta* and *S. ovata* but not by *S. minor* are the slightly emarginate 5th thoracic segment, the presence of two setæ on joints 14 and 18 of the antennules but not on the intermediate joints, the outer edge lamina, ending distally in a tooth, on the 1st basal joint of the 2nd and 3rd feet, and the outer edge spine on both 1st and 2nd joints of the exopodite of the 1st foot.

*SCOLECITHRIX LAMINATA*, sp. n. (Pl. 8. figs. 5–8.)

*Description*.—Length, ♀, 2·3 mm.; cephalothorax 1·86 mm.; abdomen ·44 mm. Cephalothorax (Pl. 8. fig. 5) robust, uniformly oval in dorsal and lateral view. *Th* 5 uniformly rounded in lateral view. Abdomen less than one-fourth the length of the cephalothorax, the genital segment being equal in length to the two following segments, which are both of equal length. Anal segment very short. The genital segment is parallel-sided in dorsal view but markedly constricted anteriorly in lateral view.

Length of antennular joints in ·01 mm. :—

1	2	3	4	5	6	7	8-9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24-25
12	10	7	7	7	6	7	11	6	7·5	8·5	11·5	12	12	12	12	13	12	13	12	10·5	15	18

There are two setæ on the 14th and 18th joints.

Antennæ with *ri* about two-thirds as long as *re* and not so thick. Mandibles with *ri* and *re* approximately equal. 1st maxillæ of the normal *Scolecithrix* type; 2nd maxillæ with about seven worm-like and two bud-like setæ. Maxillipeds with no distinctive features.

1st feet with *se* on all joints of *re*, *se* on *re* 1 about half as long as *re* 2, *se* on *re* 2 not reaching to the end of *re* 3; the shoulder on *ri* about two-thirds as long as the whole joint. *B* 1 of 2nd and 3rd feet (Pl. 8. figs. 6, 7) with a laminate ridge, occupying the proximal two-thirds of the outer margin and ending in a sharp tooth; on the inner margin the *si* is seated on a well-marked projection. There is no laminate ridge on *B* 1 of the 4th foot, but the projection on the inner margin is very prominent and bears a very small *si*. The spinulation on the lower faces of the joints of the swimming feet is best seen in the figures. There is also a very fine spinulation present over the greater part of the upper, anterior, surface. *st* of *re* of 2nd foot with 39 serrations, counting the most minute, *st* of *re* of 3rd foot with 42 serrations, *re* of 4th foot missing; 5th foot (Pl. 8. fig. 8) with a short basal joint imperfectly separated from the 2nd joint, which is slightly tapered and has a distinct elbow or abrupt curve inwards, a very small terminal seta, an inner

edge seta about four-fifths as long as the joint near the top of the joint, and a slight notch on the outer edge. An oblique longitudinal groove runs along the distal half of the joint.

This species seems to be most likely related to *S. emarginata* and *S. ovata*.

*Distribution*.—One specimen was taken in a vertical haul (22 b) from 750 to 500 fathoms. This species was also found in a tow-net attached to a trawl which was fished off the west coast of Ireland in August 1907, in 468–560 fathoms, by the Irish fishery cruiser 'Helga.'

#### SCOLECITHRIX ACUTA Wolfenden.

*Scolecithrix acuta* Wolfenden, 1911.

? *Scolecithrix angusta* Esterly, 1911.

? *Scolecithrix latipes* T. Scott, 1893.

*Lophothrix latipes* G. Sars, 1924.

#### *Distribution*.—

At 100 fms. (30 g), 1 specimen, ♀, stage V; (34 d), 1 specimen, ♀.

200 „ (36 g), 1 specimen, ♂, stage V.

The female specimen agrees in form with Wolfenden's figures and description of a species taken by the 'Gauss' in the Atlantic Ocean. It is, however, slightly larger, measuring 3.1 mm. instead of 2.65, and the 5th feet differ in having three free joints instead of two as in the 'Gauss' specimen, the segmentation between the 2nd and 3rd joints being almost complete instead of being indicated at its point of origin as in Wolfenden's figure.

*S. angusta*, length 3.14 mm., described by Esterly from the Gulf of California, also agrees closely with the 'Research' specimen. It is probable that *S. angusta* has also three-jointed 5th feet, although only two joints (which in that case would represent the 2nd and 3rd) are shown in Esterly's figure. If *S. angusta* and *S. acuta* should prove to be identical, the description of the former has the priority by some three months.

A closely-allied species, which may also prove identical, is *S. latipes* T. Scott from the Gulf of Guinea. The acute point on the 5th thoracic segment is not indicated in Scott's figure or description; it may not be a constant character, but the remaining characters agree fairly well, though the 5th foot has only three terminal spines, and the segmentation between its second and third joints is intermediate between the conditions found in *S. acuta* and in the 'Research' specimen. Sars, who has figured a specimen identical with mine and referred it to the genus *Lophothrix*, considers that it belongs to Scott's species.

This species has affinities with *S. laminata* and *S. ovata*.

Length, ♀, 3.1 mm.; stage V ♂, 2.4 mm.

#### SCOTTICALANUS THORI With.

*Scotticalanus persecans* Farran, 1908.

*Scotticalanus Helena* Scott, 1909.

*Scotticalanus persecans* Sars, 1924.

*Distribution.*—

At 100 fms. by day in 0 out of 12 hauls.  
                   by night 2           9 hauls (3 specimens, 2 ♀, 1 stage V).  
 Between 400–300 fms. in 2 out of 3 hauls (2   "   , ♀).  
                   500–400 fms. 1           3           (1 specimen, stage V ♂).

Length, ♀, 5·76 mm.; stage V ♂, 4·6 mm. With (1915) has proposed the name *S. Thori* for the Atlantic species with rounded *Th* 5, which I had formerly recorded as *S. persecans*. Scott considers, possibly correctly, that *Undina Helene* of Lubbock is this species.

## SCOTTOCALANUS SECURIFRONS T. Scott.

*Distribution.*—

At 50 fms. by day 0, by night in 1 out of 5 hauls (1 specimen, ♂).  
       75           0,                   1           8           (1   "   ♂).  
       100          0,                   1           9           (1   "   ♂).  
       300 fms. (1 specimen, stage V).  
 Between 300–200 fms. in 1 out of 3 hauls (1 specimen, stage V).

These records suggest a daylight range of about 350–250 fathoms, with males coming up to the epiplankton by night. It is a remarkable coincidence that in the 'Research' collections all the adults of *S. securifrons* were males and of *S. Thori* females.

Length, ♂, 4·8–4·9 mm.

## LOPHOTHRIX FRONTALIS Giesbr.

*Distribution.*—

Horizontal net, 450 fms. (2 specimens, 1 ♀, 1 stage V).  
 Vertical net, 400–200 fms. in 1 out of 3 hauls (1 specimen, ♀).  
                   500–400           1           3           (1   "   stage V).  
                   750–500           1           4           (1   "   ♀, dead).

Length, ♀, 5·65–6·0 mm.; stage V, 4·75–4·9 mm.

## XANTHOCALANUS MUTICUS G. O. Sars.

*Distribution.*—

Vertical net, 1000–750 fms. in 2 out of 3 hauls (2 specimens).

Length, ♀, cephalothorax broken, abdomen 1·2 mm.; stage V ♂, 4·5 mm. Sars's description and figures agree closely with my specimens, the form of the 2nd maxillæ, with a very coarsely denticulated spine on the 4th lobe and an almost smooth spine on the 5th lobe, and of the 5th feet, with two short joints, is very characteristic. The spines of the 5th feet are missing in the female specimen, but there are indications that two at least had been present at the extreme tip of the 2nd joint. There are two glandular pores on the face of the 2nd joint.

## UNDINELLA SIMPLEX (Wolfenden).

*Xanthocalanus simplex* Wolfenden, 1906.*Undinella brevipes* Farran, 1906.*Distribution.*—

		By day in			By night in
At	50 fms. }	0 out of 22 hauls.			1 out of 5 hauls (2 specimens).
	75				1     8     (1 specimen).
	100				2     9     (2 specimens).
At	200 fms. by day	(1 specimen).			
	250	(1     "     ).			
	350	(1     "     ).			

Between 750–500 fms. in 1 out of 4 hauls (1 specimen).

Present by day in very small numbers from 200 to below 500 fathoms, a few specimens coming up into the lower epiplankton by night.

Length, ♀, 1.5–1.53 mm.

This species has already been recorded by Wolfenden, under the name of *Xanthocalanus simplex*, from 500 fathoms off the west coast of Ireland, and I have recorded it from the same locality as a new species, not having recognized its identity with Wolfenden's species.

## ONCHOCALANUS sp. ?

One specimen, stage III, was taken in a vertical haul between 300–400 fathoms. Length 3.06 mm. As this specimen had no crest it probably belongs to *O. hirtipes* or *O. affinis*, but at this early stage it is not possible to be certain.

## CEPHALOPHANES REFULGENS G. Ó. Sars.

*Distribution.*—One specimen, ♀, in a vertical haul between 1000–750 fathoms.

Length, ♀, 4.2 mm.

This is evidently a typically deep-water species.

## PHAENNA SPINIFERA Giesbr.

*Distribution.*—

		By day in			By night in
At	0 fms. }	0 out of 22 hauls.			} 0 out of 10 hauls.
	25				
	50				
	75		2	3 hauls (2 specimens).	1     5 hauls (2 specimens).
	100		7	12 hauls, with .18 %.	1     8     (2     "     ).
					4     9 hauls, with .03 %.
At	150 fms. in	1 out of 1 haul (2 specimens).			
	200	1     2 hauls, with .05 %.			

Occurs not infrequently between 100 and 200 fathoms and occasionally at 50–75 fathoms, but always in very small numbers.

Length, ♀, 2.34 mm. ; ♂, 2.22 mm.

## CENTROPAGES TYPICUS Kröyer.

*Distribution.*—

By day in				By night in					
At 0 fms.	9 out of 9 hauls, with 2·5	} Per cent.	23·0	3 out of 4 hauls, with ·44	} Per cent.	8·6	cent.		
25	6			6				5	6
50	7			7				5	5
75	3			3				8	8
100	10			12				9	9
		} of aver.			} of aver.				
		} haul.			} haul.				
At 150 fms. in 1 out of 1 haul, with ·54		} Per cent.			} of average				
200	1	} ·05			} haul.				
250	2	} ·08							
300	1	} ·2							
350	1	} ·6							
Between 150- 50 fms. in 0 out of 1 haul, with 0		} Average specimens			} per 100-fathom				
200-100	3	} 6		2					
250 150	2	} 3		2					
300-200	0	} 3		0					
400-300	1	} 3		·3					
500-400	2	} 3		1·3					
750-500	2	} 4		·7					
1000-750	1	} 3		·8					

This species is normally purely epiplanktonic. Individual hauls show great variation in the numbers present in the epiplankton at various stations, the highest numbers by day being at the surface 15 per cent. (21 e); 25 fms., 53 per cent. (35 w) and 52 per cent. (34 g); 50 fms., 24 per cent. (33 c); 75 fms., 15·2 per cent. (35 e); 100 fms., 19·5 per cent. (35 f). By night the highest numbers were: surface 1·4 per cent. (25 i); 25 fms., 19 per cent. (33 e); 50 fms., 10·8 per cent. (33 f); 75 fms., 20·6 per cent. (33 h); 100 fms., 8·6 per cent. (32 n) (35 d). It seems evident that *C. typicus* was present in unusually high percentage at Stations 33 and 35 at all depths down to 100 fathoms, and that consequently the table given above can only show very roughly the average numbers present, and is quite unreliable as an indication of the distribution at any particular depth by day or night. The few records from deep water, chiefly from Station 35, are too many to be entirely accidental, and as they are nearly all of immature specimens, apparently alive, we may suppose that a few specimens losing their way sink as far as these lower layers.

As I have not been able to distinguish between immature specimens of *Centropages typicus* and *C. Chierchia*, I have, on the few stations on which the latter species occurred, divided all immature *Centropages* between these two species in the proportion in which the adults were present.

Length, ♀, 1·46-1·63 mm.; ♂, 1·56-1·64 mm.

## CENTROPAGES CHIERCHIA Giesbr.

The records of this species are confined to two adjacent stations, Nos. 30 and 31, and a third, No. 35, about 8 miles distant, but separated by a time-

interval of  $3\frac{1}{2}$  days from No. 31. On Stations 30 and 31 it was present in considerable numbers. The highest figures were : surface (day) 2 per cent. ; 25 fms. (day) 7.5 per cent. ; 50 fms. (night) 13 per cent. ; 75 fms. (day) 15 per cent. ; 100 fms. (day) 8 per cent. On Station 35 the numbers were always less than 1 per cent. No specimen was taken below 100 fathoms.

*C. Chierchia* was first recorded from the neighbourhood of Gibraltar, and its presence in the 'Research' collections is possibly to be regarded as an indication of Mediterranean water carried northwards. The scarcity of records of *C. Chierchia* from farther north is not conclusive evidence of a limited distribution, as, without a close inspection, it may easily be mistaken for *C. typicus*, and overlooked when that species is plentiful, though when once the most distinctive characters have been noticed, in the male the form of the exopodite of the right 5th foot and in the female the lateral outline of the genital segment, there is no difficulty about the identification.

Length, ♀, 1.55-1.65 mm. ; ♂, 1.68-1.75 mm.

#### METRIDIA LUCENS Boeck.

##### Distribution.—

By day in				By night in			
At 0 fms.	6 out of 9 hauls, with 3.1	Per	4 out of 4 hauls, with 9.4	Per			
25	5	0.8	5	6	13.8	cent.	
50	4	0.2	5	5	18.3	of	
75	2	4.8	8	8	19.3	aver.	
100	11	5.7	9	9	23.4	haul.	
At 150 fms. in 1 out of 1 haul, with 31.5		Per cent.					
200	2	31.2					
250	2	16.6					
300	1	34					
350	1	32					
Between 150- 50 fms. in 1 out of 1 haul, with 270							
200- 100	6	6	123				
250- 150	3	3	184				
300- 200	3	3	72				
400- 300	3	3	184				
500- 400	3	3	153				
750- 500	4	4	172				
1000- 750	3	3	149				
1250-1000	2	2	46				
1500-1250	1	1	50				
2000-1500	1	1	1.2				

This is by far the most abundant species in the collection, though in individual hauls its numbers are often exceeded by others. In the epiplankton by day it is very scarce, but by night it invades the upper waters in large numbers, forming, with *Pleuromamma robusta* and *Pleuromamma gracilis*, which exhibit similar movements, the greater part of the population above 100 fathoms during the hours of darkness. Judging by the closing nets, it is, by day, uniformly distributed down to 1000 fathoms, but it is



evident, from inspection of the specimens in the deeper hauls, that between 750 and 500 fathoms about two-thirds and between 1000 and 750 fathoms about seven-tenths were dead when caught, being for the most part empty skins. Below 1000 fathoms all the specimens were dead. Its range of abundance cannot, therefore, be put below 500 fathoms.

Length, ♀, 2.4–2.49 mm.; ♂, 1.8–1.92 mm.

**METRIDIA PRINCEPS** Giesbr.

*Distribution.*—

Between 400–	300 fms. in 2 out of 3 hauls, with 1				
500–	400	1	3	.7	} Specimens per 100-fathom haul.
750–	500	1	4	.3	
1000–	750	2	3	.8	
1250–	1000	0	2	0	
1500–	1250	1	1	(1 specimen).	
2000–	1500	1	1	(1 „ )	

The optimum range seems to be between 1000 and 300 fathoms, with an extension downwards in small numbers to below 1500 fathoms. Scott's 'Siboga' records indicate a similar distribution in depth, the shallowest haul in which it was taken being 700–0 metres. Wolfenden (1911) has recorded it from the South Atlantic from between 1000 and 3000 metres.

Length, ♀, 7.1–7.9 mm.

**METRIDIA VENUSTA** Giesbr.

*Distribution.*—

At 250 fms. in 2 out of 2 hauls, with 1.6					
300	1	1	1.1	} Per cent. of average haul.	
350	1	1	1.8		
Between 250–	150 fms. in 3 out of 3 hauls, with 2.3				
300–	200	1	3	2.0	} Average specimens per 100-fathom haul.
400–	300	2	3	6.3	
500–	400	2	3	2.7	
750–	500	2	4	.3	
1000–	750	2	3	.4	

Not taken above 250 fathoms in the horizontal nets or above 150 fathoms in the vertical nets.

The normal range lies between 200 and 500 fathoms, with occasional specimens down to below 750 fathoms and possibly an optimum at 300–400 fathoms.

Length, ♀, 2.82–2.9 mm.; ♂, 2.59–2.64 mm.

**METRIDIA BREVICAUDA** Giesbr.

*Distribution.*—

At 250 fms. in 1 out of 2 hauls (1 specimen).					
300	1	1 haul, with 2		} Per cent. of average haul.	
350	1	1	1.6		

Between 300- 200 fms. in 1 out of 3 hauls, with 1·7				Average specimens per 100-fathom haul.
400- 300	3	3	3·3	
500- 400	2	3	5·7	
750- 500	4	4	9·7	
1000- 750	1	3	·4	
1250-1000	2	2	·6	
1500-1250	0	1		
2000-1500	1	1		(1 specimen).

The general range resembles that of *M. venusta*, lying mainly between 300 and 750 fathoms. It is more plentiful than that species and the optimum lies about 200 fathoms deeper, viz. between 750 and 400 fathoms.

Length, ♀, 1·8-1·95 mm.

#### PLEUROMAMMA ROBUSTA (Dahl).

##### Distribution.—

Depth.	By day in			By night in		
0 fms.	0 out of 9 hauls, with 0	·18	Per cent.	2 out of 4 hauls, with 3·2	13	Per cent.
25	2	6	·23	6	6	16·6
50	3	7	·9	5	5	12·7
75	2	3	·46	8	8	17·2
100	7	12		9	9	

At 150 fms. in 1 out of 1 haul, with 13			
200	2	2	11·2
250	2	2	23·3
300	1	1	13·1
353	1	1	·1·8

Between 150- 50 fms. in 1 out of 1 haul, with 7			
150- 100	1	1	6
200- 100	6	6	49·5
250- 150	3	3	79
300- 200	3	3	125
400- 300	3	3	60
500- 400	3	3	25
750- 500	4	4	6·1
1000- 750	2	3	8·8
1250-1000	1	2	1

Average  
specimens  
per  
100-fathom  
haul.

In the epiplankton it forms less than 1 per cent. by day, but by night it is one of the most abundant species. The normal day range, as shown by both vertical and horizontal hauls, lies between 150 and 400 fathoms, with a distinct maximum at 200-300 fathoms.

Length, ♀, 3·5-3·8 mm. ; ♂, 3·0-3·4 mm.

#### PLEUROMAMMA ABDOMINALIS (Lubbock).

##### Distribution.—

Depth.	By day in		By night in	
25 fms.	1 out of 6 hauls (1 specimen).		2 out of 6 hauls (2 specimens).	
50			2	5 (3 " )
75			1	8 (2 " )
100	0 out of 22 hauls.		3	9 (3 " )

At 200 fms. in 1 out of 2 hauls (2 specimens).  
 250            1            2            (1 specimen).

Between 200–100 fms. in 1 out of 6 hauls (1 specimen).  
 250–150            0            3            (1 „ ).  
 300–200            2            3            (2 specimens).

This distribution is similar to that of *P. robusta*, but *P. abdominalis* is very much scarcer than that species, over 200 specimens of the latter having been taken to one of the former.

Length, ♀, 3·36 mm.

*PLEUROMAMMA GRACILIS* (Claus).

*Distribution.*—

Depth.	By day in			By night in				
0 fms.	1 out of 9 hauls (1 specimen).			4 out of 4 hauls, with 4			} Per cent. of average haul.	
25	3	6 hauls, with	·3	6	6	13		
50	1	8	·14	5	5	15·2		
75	1	3	·75	8	8	11·4		
100	6	12	·79	9	9	17		
At 150 fms. in 1 out of 1 haul, with 11·8								
200	2	2	17·3	} Per cent. of average haul.				
250	2	2	4·8					
300	1	1	2·6					
350	1	1	4·6					
Between	150- 50 fms. in 1 out of 1 haul, with 25			} Average specimens per 100-fathom haul.				
	200-100	6	6					79
	250-150	3	3					271
	300-200	1	3					11
	400-300	0	3					0
	500-400	1	3					·7
	750-500	3	4					1·2
	1000-750	1	3	11·3				

Like *Metridia lucens* and *Pleuromanma robusta* this species forms less than 1 per cent. of the epiplankton during the day, but by night becomes very abundant. The day maximum lies between 150 and 250 fathoms with very small numbers below that horizon. The numbers between 750 and 1000 fathoms are higher than between 300 and 750 fathoms, but the former record is based on a single haul which may have been exceptional.

Length, ♀, 2·2–2·34 mm.; ♂, 1·72–1·82 mm.

*PLEUROMAMMA XIPHIAS* (Giesbr.).

*Distribution.*—

Depth.	By day in		By night in		
0 fms.	0 out of 9 hauls.		1 out of 4 hauls (1 specimen).		
25	1	6 hauls (1 specimen).	3	6 hauls, with	·17
50	}	0 out of 22 hauls.	5	5	·16
75			5	8	·06
100			6	9	·16
					} Per cent. of average haul.

At 150 fms. in 1 out of 1 haul (1 specimen).

200	0	2 hauls
250	0	2
300	1	1 haul (1 specimen).
350	1	1 (1 „ )).

Between	300-200 fms.	in 1 out of 3 hauls,	with 1	} Average specimens per 100-fathom haul.
	400-300	2	3	
	500-400	2	3	
	750-500	2	4	
	1000-750	2	3	

This distribution also resembles that of *P. robusta*. There is an indication that the day optimum lies below 250 fathoms. The upward migration by night is clearly marked.

Length, ♀, 4.7-5.0 mm.; ♂, 4.7 mm.

*LUCICUTIA FLAVICORNIS* Claus. (Pl. 9. figs. 1-3.)

*Lucicutia flavicornis* Giesbrecht, 1892.

*Lucicutia flavicornis* Farran, 1908.

In recording this species from the west coast of Ireland (1908), I remarked on the fact that the specimens seemed to fall into two groups which at that time I regarded as being within the possible limits of variation of one species, but now that a much larger number of specimens have been examined, and the differences between the groups found to be constant and more numerous than appeared at first, it is not possible any longer to include both groups under one species. I have accordingly retained one group under *L. flavicornis* and proposed below the new name of *L. gemina* for the other. Giesbrecht has commented on the variability of *L. flavicornis* in the Mediterranean, but he only mentions two of the characters which separate the females of *L. flavicornis* and *L. gemina*, namely the serration of the *re* 3 of the 5th foot and the form of the furca. The form of the genital segment and the furcal setæ, however, also furnish diagnostic characters which may be looked on as free from variation.

Figures are given of the lateral view, the furca and the 2nd basal of the 1st foot of the female for comparison with the corresponding figures of *L. gemina*, and it may be said that the figures of *L. flavicornis* given by Giesbrecht in his Monograph on pl. xix. figs. 2, 3, 15, 17, 20, 22, 23, 38, are all good illustrations of those appendages as seen in the 'Research' specimens. The male, unlike the female, has the furcal rami parallel and contiguous; the innermost seta is short, being about two-fifths of the furcal length.

Length, ♀, 1.47-1.58 mm.; ♂, 1.44-1.56 mm.

*Distribution of L. flavicornis + L. gemina.*—The vertical distribution of the two species is very similar, and as the males on account of their resemblance were not separately distinguished when the collection was first sorted,

it is not now possible without re-examination of the whole collection to give a separate account of their numerical distribution. Both sexes of both species have accordingly been combined in the following table.

Depth.	By day in				By night in			
0 fms.	2	out of 9 hauls,	with .06	} Per cent.	1	out of 4 hauls,	with .1	} Per cent.
25	1	6	(1 spec.).		4	6	.2	
50	1	8	( „ ).		5	5	.55	
75	2	3 hauls,	with .37		7	9	.76	
100	8	12	.71	} aver. haul.	9	9	.67	} aver. haul.

At 150 fms. in	1	out of 1 haul,	with 3.1	} Per cent. of average haul.
200	1	2	.21	
250	2	2	.34	
300	1	1	.68	
350	1	1	.37	} aver. haul.

* Between	150–	50 fms. in	1 out of 1 haul,	with 3	} Average specimens per 100-fathom haul.
	150–	100	1	1	
	200–	100	6	6	
	250–	150	3	3	
	300–	200	0	3	
	400–	300	1	3	
	500–	400	2	3	
	750–	500	3	4	
	1000–	750	0	3	
	1250–	1000	1	2 hauls (1 specimen, dead).	

The range of the combined species is from below 500 fathoms to the surface, the numbers in the epiplankton being distinctly more numerous by night. The day maximum lies in the neighbourhood of 150 fathoms, as indicated by both horizontal and vertical hauls.

*L. flavicornis* ♀ is approximately twice as numerous as *L. gemina* ♀, and a slight difference in distribution in the epiplankton is perhaps indicated by the fact that *L. gemina* ♀ was not taken at 0 or 25 fathoms and only once at 50 fathoms.

#### LUCICUTIA GEMINA, sp. n. (Pl. 9. figs. 4–8.)

*Description*.—Length, ♀, 1.75–1.86 mm.; ♂, 1.63–1.72 mm. Female (Pl. 9. fig. 4):—Cephalothorax elongate-ovate, the rostrum just visible in dorsal view. Abdomen  $\frac{1}{7}$  of cephalothorax, genital segment about  $2\frac{1}{2}$  times as long as any of the three following segments, which are about equal in length. Genital boss about equal in diameter to the thickness of the genital segment. Furcal rami (Pl. 9. fig. 5) slightly more than five times as long as wide and twice as long as the 2nd and 3rd abdominal segments together; they have each four terminal setæ, the innermost being very small and slender, less

\* In the tabular list of species in the vertical hauls, *L. flavicornis*, and *L. gemina* have been separated.

than one-fourth the length of the outer edge of the furca; the next seta is large and about twice as thick as the two outermost setæ. Antennules reaching about to the middle of the furca, the length of the joints in .01 mm. being :—

No: 1 2 3 4 5 6 7 8 9 10-11-12 13 14 15 16 17 18 19 20 21 22 23 24 25  
Size: 6 4 3.6 3.2 3.6 3.6 4 4 4 4-5.2-5.2 6.4 8 8 10.4 12 14 15.2 12 12 12 12 10.8 5.2

The jointing agrees very nearly with that of *L. flavicornis* as figured by Giesbrecht, joints 10-12 being partially fused and joint 19 being the longest; the jointing between 8 and 9 is not so clearly marked as in Giesbrecht's figure. The other cephalic appendages agree with those of *L. flavicornis*. 1st foot with 3-jointed *ri* and a low cylindrical process on *b2* (Pl. 9. fig. 6). 2nd (Pl. 9. fig. 7) and 3rd feet similar to those of *L. flavicornis*, but with the fine serrations on the outer margins of *re2* and the proximal third of *re3* rather more distinctly marked. 4th foot similar to 2nd and 3rd, but with the marginal serrations almost obsolete. 5th foot (Pl. 9. fig. 8) with a short *si* on *re2*, not reaching to the base of the first *si* of the following joint.

Male resembling the female in general proportions and appearance except for the jointing of the abdomen and the 5th feet, the proportional lengths of the abdominal joints and furca in mid-dorsal measurement being 7.5, 8, 8, 8, 7.5, 23. The furcal rami are parallel and contiguous, and there is a very minute transparent innermost terminal seta which is about one-eighth of the length of the outer margin of the furca.

It may be useful to tabulate the principal points in which *L. gemina* differs from *L. flavicornis*.

#### L. FLAVICORNIS.

♀. Furcal rami widely separated, slightly divergent. Genital boss of medium size. Solid rounded tubercle on *2b* of 1st foot. 5th foot with toothed outer margin to *re3*, and *si* of *re2* reaching beyond base of prox. *si* of *re3*. Length ca. 1.5 mm.

♂. Furcal rami parallel and touching, innermost furcal seta small. Anal seg. shorter than 4th abd. seg. *B2* of left 5th foot with four minute teeth on inner margin. *B2* of right 5th foot with protruding inner margin. Length ca. 1.5 mm.

#### L. GEMINA.

♀. Furcal rami parallel and touching. Genital boss small. Low flat cylindrical tubercle on *2b* of 1st foot. 5th foot with smooth outer margin to *re3*, and *si* of *re2* barely reaching to base of prox. *si* of *re3*. Length ca. 1.8 mm.

♂. Furcal rami parallel and touching, slightly longer proportionally than in *L. flavicornis*. Innermost furcal seta very minute. Anal seg. equal to 4th abd. seg. *B2* of left 5th foot with acuminate inner angle and no teeth. *B2* of right 5th foot straight. Length ca. 1.7 mm.

#### LUCICUTIA MAGNA Wolfenden.

##### Distribution.—

At 300 fms. in 1 out of 1 haul, with 1.2 } Per cent. of haul.  
350 1 1 .16 }

Between 300- 50 fms. in 0 out of 10 hauls.		
400-300	2	3 hauls, with 1·7 per 100-fathom haul.
500-400	0	3 hauls
750-500	0	4
1000-750	1	3 hauls (1 specimen).

This is a very scarce species in this collection compared with *L. curta*, and its range is limited to 300-400 fathoms, with the exception of a single specimen at 1000-750 fathoms. On the west coast of Ireland *L. curta* and *L. magna* are about equal in numbers.

Previous records (Wolfenden, 1904 ; Farran, 1908) suggest that it has a much wider vertical range, but it must be remembered that when a species is present in very small numbers, the chance of taking it at all points of its range is very small, and on this occasion the captures at 300-400 fathoms probably represent the maximum of a wider range.

Length, ♂, 3·36 mm.

#### LUCICUTIA OVALIS Wolfenden.

*Lucicutia ovalis* Wolfenden, 1911.

*Distribution.*—At 100 fathoms in 2 out of 21 hauls, two specimens, both ♀.

Length, ♀, 1·4-1·6 mm. In spite of some small differences from Wolfenden's description, in particular the more clearly marked dorsal thoracic segmentation and the absence of a notch in the outer margin of *re* 3 of the 4th foot, the agreement is so close, especially as regards the shape of the body and of the abdomen with its large globular genital pad and short furcal setæ and the 5th foot with its very short terminal spine on *re* 3 and its long *re* 1, that there can be no doubt about the identification. Both the 'Research' specimens were strongly curved, the abdomen being bent downwards and the genital pad pressed against the base of the last pair of legs. Wolfenden's specimens were taken in the tropical South Atlantic.

#### LUCICUTIA CURTA Farran.

*Distribution.*—

At 300 fms. in 1 out of 1 haul (1 specimen).

350            1            1 haul, with ·74 per cent.

Between 200- 100 fms. in 2 out of 6 hauls (2 specimens).

300- 150	0	6 hauls.	
400- 300	3	3 hauls, with 6·3	Average 13·3 } specimens ·9 } per 1·3 } 100-fathom ·6 } haul.
500- 400	3	3	
750- 500	3	4	
1000- 750	2	3	
1250-1000	2	2	

The vertical range is well marked, with a maximum at its upper limit between 500 and 300 fathoms and a downward extension in smaller numbers to below 1000 fathoms. The two specimens taken between 100 and 200 fathoms are probably stragglers and may be neglected ; one of them was evidently dead at the time of capture.

Length, ♀, 2·04-2·4 mm. ; ♂, 1·84-1·98 mm.

*LUCICUTIA SIMULANS* ? G. O. Sars. (Pl. 9. figs. 9-13.)

*Distribution*.—Between 1106-750 fms. in 2 out of 3 hauls, with .8 specimen per 100-fathom haul.

Length, ♀, 2.64-2.82 mm.; ♂, 2.52 mm.

These specimens, though slightly larger than those recorded (1920) and figured (1924) by Sars, agree otherwise with his figures and rather brief description. I give figures of the 1st and 5th feet of the female and of the exopodite of the 3rd foot, the enlarged first joint of which, and of that of the 2nd foot, furnishes a distinctive character, and also of the 5th foot of the male. Sars's specimen, a female, measured 2.4 mm.

*LUCICUTIA GRANDIS* Wolfenden.*Distribution*.—

Between 1000- 750 fms. in 1 out of 3 hauls (2 specimens, 31 d).
1250-1000                      1                      2                      (1 specimen, 31 c).

The specimen from Station 31 c, stage V, length 5.28 mm., has a pair of small projections on each side of the cephalon, one at the antero-lateral corner, the other medio-lateral, both being directed outwards. The tips of the projections are broken off, so it is possible that they may have been produced into hooked processes.

*ISOCHÆTA OVALIS* Giesbr.*Distribution*.—

Between 750- 500 fms. in 4 out of 4 hauls, with 2	} Average specimens per 100-fm. haul.
1000- 750                      3                      3                      1.1	
1200-1000                      1                      2 hauls (1 specimen).	

In small numbers in every haul between 1000 and 500 fathoms, and probably more numerous than appears from the record, as some specimens may have passed through the nets.

Length, ♀, 1.34-1.44 mm.; ♂, 1.22-1.32 mm.

Giesbrecht's species is said to have only four setæ on *ri* 3 of the 2nd foot (according to 'Das Tierreich') or of the 4th foot (according to the 'Fauna u. Flora des Golfes von Neapel'), but in the 'Research' specimens the 2nd foot has five such setæ and the 3rd and 4th feet each six setæ. The other characters agree well, though the thoracic segments do not seem to be quite so produced as in Giesbrecht's figure, and the antennules if reflexed would reach almost to the end of the furca.

Wolfenden's *Lucicutia frigida* (1911), which has a 3-jointed *ri* on the 1st foot and a 2-jointed *ri* on the 5th, is undoubtedly congeneric with this species, and seems to differ only in small characters, such as the presence of a *si* on *ri* 1 of the 1st foot and a slightly shorter *si* on *re* 2 of the same foot.



The anal segment is proportionately a little longer, as is also the whole abdomen, but both Giesbrecht's specimen and mine seem to have been slightly contracted. If it should prove that the Pacific species has normally only four setæ on *ri* 3 of 2nd foot, it may be necessary to give a new name to the Atlantic species, but for the present it is enough to call attention to the possible difference.

*DISSETA PALUMBOI* Giesbr.

*Heterorhabdus grandis* Wolfenden, 1904.

*Disseta atlantica* Wolfenden, 1911.

*Distribution.*—

Between 500–400 fms. in 1 out of 3 hauls (1 specimen).			
750–500	2	4 hauls, with .5 per 100-fathom haul.	
1000–750	1	3	(1 specimen).

Length, ♀, 6.36–6.95 mm.; ♂, 6.32 mm.

The status of the Atlantic form of this species seems to need some examination. Giesbrecht in 1889 described *D. palumboi*, ♀, length 5.7 mm., from the Pacific. Wolfenden in 1904 described as *Heterorhabdus grandis* a species of *Disseta*, ♀, length 6.6 mm., from the North Atlantic, giving no characters by which it could be distinguished from *D. palumboi*. In 1905 he also described the male of this species, and gave the size of the female as 7.0 mm. G. O. Sars in 1905 and Farran in 1908 recorded *D. palumboi* from the North Atlantic. Esterly in 1906 described independently as *Disseta grandis*, ♀, length 8.3 mm., a form from the Gulf of California which seems to differ in some small points from *D. palumboi*, and also in 1911 a much larger species, ♀, length 9.4 mm., as *D. maxima*. In 1911 Wolfenden re-described, as it seems, the Atlantic form, which he had previously named *grandis*, as *D. atlantica*, from specimens taken by the 'Gauss,' and pointed out some characters in which it differed from Giesbrecht's Pacific species. If these characters prove reliable, the name for the Atlantic species will properly be *D. grandis* Wolf., and Esterly's species will require a new name. I do not think that they can be depended on at present.

These characters are: (a) 1 antennule extending beyond the furca by 4 joints instead of 6; (b) *ri* of antenna and mandible longer than *re* instead of equal to it; (c) *ri* of maxilla with 12 setæ instead of 9. As regards these points, it may be remarked (a) that this method of measuring the antennule is not very accurate; (b) the *ri* of the antenna is longer than the *re* both in Giesbrecht's figure and in my specimens. My specimens also have the *re* of the mandible longer than the *ri*, as in Giesbrecht's figure; (c) Giesbrecht's description of the maxilla is not easy to follow without a figure, but the number of the setæ on the *ri*, viz. 12, agrees with that found by Wolfenden.

For these reasons it seems best for the present to consider the Atlantic species as *D. palumboi*.

**HETERORHABDUS ABYSSALIS (Giesbr.).***Distribution.*—

		By day in		By night in	
At 50 fms.	nil			1 out of 5 hauls (1 spec.)	
75				8 hauls, with .05	% of
100	out of 12 hauls, with .37			9	aver.
					haul.
At 150 fms. in 1 out of 1 haul, with .63					
200	1 2				Per cent.
250	2 2				of average
300	1 1				haul.
350	1 1				
Between 150– 50 fms. in 1 out of 1 haul, with 2					
150– 100	1 1				
200– 100	6 6				
250– 150	3 3				
300– 200	1 3				
400– 300	1 3				
500– 400	2 3				
750– 500	4 4				
1000– 750	3 3				
1250–1000	1 2				
1500–1250	1 1				

It seems clear that the day maximum lies between 100 and 200 fathoms, although the actual numbers are not large. A small upward migration by night is also indicated. The increase, which is shown below 750 fathoms, contains a fair proportion of dead specimens.

Length, ♀, 2.2–2.6 mm.; ♂, 2.0–2.6 mm.

**HETERORHABDUS NORVEGICUS Boeck.**

*Heterorhabdus norvegicus* Farran, 1905, 1908.

*Distribution.*—

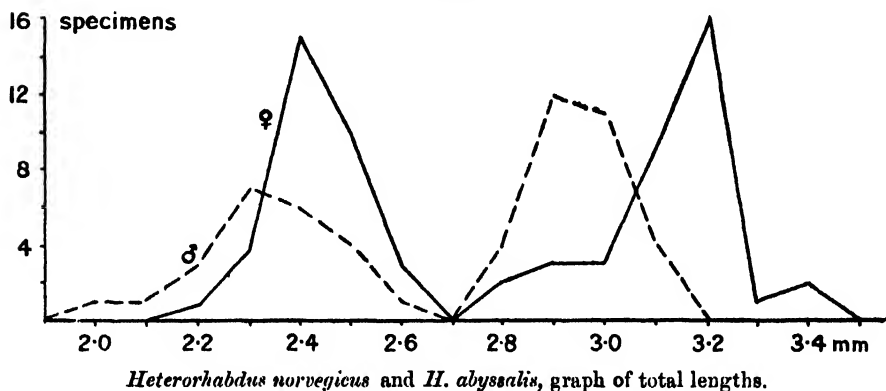
At 200 fms. in 1 out of 2 hauls, with .05			
250	2 2	1.1	Per cent.
300	1 1	1.4	of average
350	1 1	2.4	haul.
Between 300–200 fms. in 1 out of 3 hauls, with 1			
400–300	2 3	4.3	Average
500–400	1 3	.3	specimens
750–500	3 4	.3	per
1000–750	2 3	.7	100-fathom
			haul.

The range of this species both upwards and downwards is distinctly more limited than that of *H. abyssalis*. Its optimum range, 200–400 fathoms, lies somewhat deeper, and within that optimum range it may perhaps be regarded as slightly more plentiful than *H. abyssalis*, though the records are too irregular for certainty.

Length, ♀, 2.8–3.4 mm.; ♂, 2.8–3.1 mm.

It is not perfectly clear to me whether these specimens are true *H. norvegicus* or a closely-allied southern form, perhaps *H. profundus*. It is, at any rate, the species which I have already recorded as *H. norvegicus* from the west coast of Ireland. It undoubtedly lacks the only definite character which is usually relied on to separate *H. norvegicus* from its nearest ally, *H. abyssalis*, namely the possession of a very short subterminal seta on the *re* 3 of the right 5th foot of the male. In all the specimens examined this seta is of the same length as in *H. abyssalis*, and it is not possible to separate the two species except by size. In respect of size, however, the separation is clear. The following graph, which gives the total length in .1-mm. groups of 123 specimens of both species, taken at random from a large number of tow-nettings, shows a distinct gap of .1 mm. between the two groups in both sexes. Doubtless a large number of measurements would show that some

FIG. 2.



overlapping takes place. In that case some specimens would be indistinguishable, though probably some physiological barrier, perhaps correlated with some small structural character which I have overlooked, keeps them apart.

*H. norvegicus* was described by Boeck in 1872 (Forh. Selsk. Christ.) without mention of any definite characters or of size. Dahl, besides recording *H. norvegicus* (Verh. Deutsch. Zool. Gesell. 1894), to which he ascribes a length of 3 mm., also describes an allied species, *H. profundus*, differing from the male of *H. norvegicus* in (a) the longer subterminal spine on *re* 3 of the right 5th foot, and (b) in having a seta on the inner edge of *re* 3 of the left 5th foot which reaches to the middle of the joint. No size is given, but presumably *H. profundus* is of the same length as *H. norvegicus*, viz. 3 mm. The 'Research' specimens agree with *H. profundus* in (a) but not in (b).

Sars ('Crustacea of Norway') has figured a large form of *H. norvegicus*, ♀, length 4.2 mm., and, in his figure of the 5th foot of the male, shows the short subterminal spine on *re* 3 of the right 5th foot, but does not mention it

in the text. Wolfenden ('Plankton Studies,' 1905) has described and figured the 5th foot of the male of *H. profundus* from the 'Gauss' collection, but has omitted the species from the complete report on the 'Gauss' Copepoda. His figure agrees in both (a) and (b) with Dahl's description.

Under these circumstances I retain the name *H. norvegicus* provisionally for the 'Research' specimens until undoubted specimens of *H. norvegicus* and *H. profundus* are available for examination.

#### HETERORHABDUS SPINIFRONS (Claus).

##### Distribution.—

By day in				By night in			
At 0 fms.	1 out of 9 hauls, with	·02	Per	0 out of 4 hauls, with	0	Per	
25	0	6	0	0	6	0	cent.
50	1	7	(1 spec.)	1	5	·1	of
75	1	3 hauls, with	·03	7	8	·1	aver.
100	11	12	·8	9	9	·4	haul.

At 150 fms.	in 1 out of 1 haul, with	·6	} Per cent. of average haul.
200	1	2	
250	2	2	
300	1	1	
350	1	1	·4

Between 150- 50 fms.	in 1 out of 1 haul, with	6	} Specimens per 100-fathom haul.
200-100	5	6	
250-150	1	3	
300-200	1	3	
400-300	2	3 hauls, with	
500-400	2	3	

The optimum seems to lie about 100-150 fathoms, the distribution rising in small numbers to 50 fathoms by night.

Length, ♀, 2·96-3·12 mm.; ♂, 2·7-3·4 mm.

#### HETERORHABDUS PAPILLIGER (Claus).

##### Distribution.—

By day in				By night in			
At 0 fms.	1 out of 9 hauls, with	·04	Per	0 out of 4 hauls, with	0	Per	
25	1	6	(1 spec.)	3	6	·1	cent.
50	0	7	0	3	5	·06	of
75	2	3 hauls, with	·2	5	8	·16	aver.
100	8	12	·2	6	9	·1	haul.

At 150 fms.	in 0 out of 1 haul.		
200	1	2 hauls (2 specimens).	
250	1	2	(2 " ).
300	1	1	(1 specimen).
350	1	1	(1 " ).

Between 150- 50 fms.	in 1 out of 1 haul (1 specimen).	
200-100	1	6 hauls, with ·5 specimens per 100-fathom haul.

The impression given by the above table is that of a very sparse and irregular distribution, mainly in the epiplankton, with no marked difference between day and night below 50 fathoms, but slightly in favour of night at and above 50 fathoms, where it was taken in 2 out of 22 hauls by day and in 6 out of 16 by night.

Length, ♀, 2·1–2·34 mm.; ♂, 2·22–2·32 mm.

### HETERORHABDUS LONGICORNIS (Giesbr.).

#### *Distribution.*—

	By day in		By night in	
At 75 fms.	0 out of 3 hauls.		1 out of 3 hauls (1 specimen).	
100	2	12 hauls (2 specimens).	5	9 hauls, with ·05 per cent.
At 150 fms.	in 1 out of 1 haul, with ·2 per cent.			
200	1	2 hauls (1 specimen).		
250	1	2 (2 specimens).		
300	1	1 haul, with ·31 per cent.		
350	0	1		
Between 200– 100 fms.	in 5 out of 6 hauls, with 1·7			
150– 150	1	3	·7	Average specimens per 100-fathom haul.
300– 200	2	3	1	
400– 300	1	3	·7	
500– 400	1	3	1·3	
750– 500	4	4	·4	
1000– 750	0	3	0	
1250–1000	1	2	·4	

The range seems to be from 75 to over 1000 fathoms, but there are not enough records to indicate a definite optimum depth. It seems to be more numerous above than below 500 fathoms.

Length, ♀, 2·94–3·5 mm.; ♂, 2·88–3·68 mm.

### HETERORHABDUS ROBUSTUS Farran.

*Heterorhabdus robustus* G. O. Sars, 1924.

#### *Distribution.*—

At 250 fms.	in 1 out of 2 hauls, with ·03		} Per cent. of average haul.
300	1	1	
350	1	1	

This species seems to occur very sparsely in a narrow zone of 250–350 fathoms. Its numbers are too small to give any expectation of its capture in the vertical closing nets. The records from the west coast of Ireland (Farran, 1908) indicate an extension to greater depths, but some of the specimens recorded may have been taken whilst the nets were being hauled.

Length, ♀, 3·48–3·6 mm.; ♂, 3·36 mm.

? *HETERORHABDUS BREVICORNIS* (Dahl).*Distribution.*—

At 300 fms. in 1 out of 1 haul (1 specimen, ♀).

Between 300–200 fms. in 1 out of 3 hauls (1 specimen, stage V).

500–300	0	6	
750–500	1	4	(1 specimen, ♀).

Length, ♀, 2.23–2.4 mm., cephalothorax 1.63–1.8 mm., abdomen .6 mm.; stage V, 1.85 mm. The female specimens are short and squat, the abdomen being about one-third of the length of the cephalothorax, the width of which in dorsal view is about two-thirds of its length. The antennules in the larger specimen measure 1.92 mm., the lengths of the terminal joints in .01 mm. being 8, 7, 7, 7.5, 3, and their diameter 3.

Wolfenden ('Plankton Studies,' 1905; Deutsche Südpol. Exp. 1911) has recorded a female of somewhat similar form under this name, but the abdomen is only one-fourth as long as the cephalothorax, and the *ri* of the maxilla has only three setæ. The 'Research' specimen, which was mounted, had five such setæ, as is the case in *H. vipera* and *H. robustus*.

It is possible that these specimens should be regarded merely as a small form of the Arctic species *H. compactus*.

*HETERORHABDUS VIPERA* (Giesbr.).*Distribution.*—

At 100 fms. (1 specimen, ♀).

150 (1 „ ♀).

Between 200–100 fms. (1 specimen, ♂).

Length, ♀, 2.63 mm.; ♂, 2.68 mm.

*H. vipera* can be distinguished from *H. compactus*, *H. robustus*, and, probably, *H. brevicornis*, with which it makes up a well-marked subsection of the genus, by its comparatively slender form.

*HEMIRHABDUS GRIMALDII* (Richard).

*Heterochæta Grimaldii* Richard, 1898.

*Heterorhabdus Grimaldii* Giesbr. & Schmeil, 1898.

*Hemirhabdus Grimaldii* Wolfenden, 1911.

*Macrorhabdus Grimaldii* G. O. Sars, 1920.

One specimen, ♀, length 7.3 mm., was taken in a vertical haul between 1000 and 750 fathoms.

Sars, in proposing a new genus for this species, seems to have overlooked the fact that Wolfenden had already done so.

**MESORHABDUS BREVICAUDATUS** (Wolfenden).*Mesorhabdus annectens* G. O. Sars, 1905.*Mesorhabdus brevicaudatus* Sars, 1924.*Distribution.*—

Between 500–400 fms. in 1 out of 3 hauls (2 ♂♂).  
 1000–750                      1                      3                      (1 ♀, dead).

Length, ♀, 3·3 mm.; ♂, 3·6 mm.

**HALOPTILUS ANGUSTICEPS** G. O. Sars. (Pl. 9. fig. 14.)*Haloptilus angusticeps* G. O. Sars, 1907, 1924.

One specimen, ♀, length 3·6 mm., was taken in a horizontal haul at 350 fathoms.

The specimen agrees with Sars's figures in most of its distinctive characters, although showing small differences in the numbers of the setæ on some of the mouth appendages possibly due to variation or perhaps to injury. Attention may be called to some characteristic features, *e.g.* the two long feathered setæ on the *re* of the first maxilla, the well-developed cutting edge of the mandible (Pl. 9. fig. 14), and the enlarged seta on each of the terminal joints of the maxillipede.

**HALOPTILUS ACUTIFRONS** (Giesbr.).*Distribution.*—

Depth.	By day in				By night in			
0 fms.	3 out of 9 hauls,	with	·06	} Per cent. of aver. haul.	1 out of 4 hauls,	with	·05	} Per cent. of aver. haul.
25	} 0	13	0		0	6	0	
50					1	5	·04	
75	1	3	·03		2	8	·01	
100	9	12	·2		7	9	·08	

At 150 fms. in 1 out of 1 haul (1 specimen).

200	0	2	} Per cent. of average haul.
250	2	2 hauls, with	
300	1	1	
350	0	1	

Between 150–50 fms. in 0 out of 1 haul.

200–100	1	6 hauls (1 specimen).
250–150	0	3
300–200	1	3 (1 " ).
400–300	1	3 (1 " ).
500–400	} 0	7
750–500		
1000–750	1	3

It seems to occur mainly in the layer 75–100 fathoms with occasional specimens from below those depths and from the surface.

Length, ♀, 3·2–3·5 mm.

*HALOPTILUS LONGICORNIS* (Claus).*Distribution.*—

		By day in		By night in	
At	0 fms.	2 out of 9 hauls, with	.1	Per cent.	0 out of 9 hauls.
25	}	0	13	0	} 5 hauls, with .1
50		3	3	.3	
75		9	12	2.1	
100					
					.4 } % of aver. haul.
At	150 fms. in	1 out of 1 haul, with	1.1	Per cent.	
200	1	2	.3	} of average haul.	
250	2	2	.7		
300	1	1	.7		
350	1	1	.9		
Between	150-50 fms. in	1 out of 1 haul, with	3	Average	
200-100	6	6	5	specimens per	
250-150	3	3	3.3	100-fathom haul.	
300-200	}	0	9		
400-300					
500-400					
750-500		1	4 hauls (1 specimen).		
1000-750		1	3 (1 „ )		

Between 200 and 400 fathoms the vertical and horizontal hauls do not agree very well, but as the numbers are so few this may perhaps be expected. There is evidently a maximum at 100-150 fathoms with few specimens outside these limits.

Length, ♀, 1.98-2.07 mm.

*HALOPTILUS BULLICEPS*, sp. n. (Pl. 9. figs. 15, 16 ; Pl. 10. figs. 1-3.)

*Description.*—All the seven specimens of this species which were obtained were in stage IV, and although there is always some doubt about the advisability of basing a description of a new species on an immature specimen, yet as the characters in this instance seem to be distinctive and sufficient to distinguish it from any known species, I have ventured to give it a name instead of consigning it to obscurity.

Length, stage IV, 3.5-3.7 mm.

Cephalothorax (Pl. 10. figs. 1, 2) slightly constricted in the middle, the anterior portion being much inflated both in dorsal and lateral view and uniformly rounded anteriorly. Rostral filaments absent. An anterior cæcum was distinctly present in one specimen ; in the others it could not definitely be made out. Abdomen about  $5\frac{1}{2}$  times in length of cephalothorax, with furcal rami nearly twice as long as broad. Antennules longer than the body by 5 or 6 joints ; in a specimen of 3.7 mm. they measured 5.1 mm. Antennæ (Pl. 9. fig. 15) with *re* about seven-tenths the length of *ri* and not quite as long as *B2*. Mandible with well-developed 2-branched palp ; cutting edge (Pl. 9. fig. 16) with a strong distal claw and 3 teeth and



2 spines on the proximal half. 1st maxillæ (Pl. 10. fig. 3) with 9 well-developed subequal spines on *li* 1, a thickened seta and a slender seta on *li* 2, one small seta on *li* 3, *B* 2 with 3 setæ, *ri* 1-jointed with a single seta, *re* with one small and 6 large setæ, the terminal seta being very long, stout, and opaque, *le* with 6 setæ. 2nd maxilla with none of its setæ thickened, 2nd basal joint nearly as long as 1st. Maxillipede moderately long, 2nd basal joint nearly equal to 1st, terminal joints together equal to 1st joint, setæ gradually increasing in length and all slender. 1st to 4th feet with 2-jointed *re* and *ri*, 5th feet with 1-jointed *re* and *ri*. Abdomen 3-jointed.

This species is characterized in stage IV by the inflated cephalon, the moderately long antennules, the short *ri* of the antennæ, the small *ri* of the 1st maxilla, which possibly in the adult bears more than one seta, and the absence of thickened claw-like setæ on lobes 5 and 6 of the 2nd maxillipedes. The adult probably measures between 5 and 6 mm. in length.

*Distribution.*—

At 100 fms. in 5 out of 21 hauls (6 specimens).

Between 200–100 fms. in 1 out of 6 hauls (1 specimen).

*HALOPTILUS PLUMOSUS* (Claus).

*Distribution.*—

At 100 fms. (24 *b*) (30 *h*), 2 specimens, stage V; (30 *y*) (35 *x*), ? 2 specimens, stage IV.

Between 750–500 fms. (1 specimen, ♀).

Length, ♀, 4.15 mm.; stage V, 3.3–3.55 mm.

As far as one can judge from the description published by Giesbrecht, *H. plumosus* is only separated from *H. ornatus* by its slightly smaller size, by having antennules equal in length to the body instead of longer by 4 or 5 joints and by the presence of 4 setæ instead of 2 on the *ri* of the 1st maxilla. The present female specimen approaches *H. plumosus* in size, and has 4 setæ on *ri* of 1st maxilla, but the antennules are longer than the body by about 4 joints. It differs from *H. ornatus* in the number of setæ on *ri* of 1st maxilla and in the form of *si* of *ri* 2 of 5th foot, which is minute, straight, and slender instead of being a small stout hook, as shown in Giesbrecht's figure. In all other respects the resemblance to Giesbrecht's figures and description is so close as to make it not impossible that the differences may be within the limits of variation of a single species. Whether this is so or not, I think that the specimen is rightly referred to *H. plumosus* in spite of its longer antennules.

The immature specimens have only 2 setæ on *ri* of one maxilla, and on some of the other appendages the full number of setæ has not been reached. They have each a distinct anterior cæcum which in the adult (which was in a very battered state) may or may not have been present.

## Genus AUGAPTILUS.

I have followed Sars (1920) in his tentative revision of the genus, in which he has retained the name *Augaptilus* for species, allied to *A. longicaudatus*, with a reduced 1st maxilla, and has proposed the collective name of *Euaugaptilus* for the heterogeneous remainder, with the exception of a small group under the name of *Centraugaptilus*, of which he made *C. Rattrayi* the type.

## AUGAPTILUS LONGICAUDATUS (Claus).

*Distribution.*—

At 0 fms. in 2 out of 13 hauls, with .05 per cent.

25	}	0	35 hauls.
50			
75			
100	3	21 hauls	(3 specimens).
150	1	1	(1 specimen).
200	0	2	
250	1	2	(2 specimens).
300	1	2	(1 specimen).
350	1	2	(1 „ ).

Between 150–50 fms. in 0 out of 1 haul.

200–100	2	6 hauls	(2 specimens).
250–150	1	3	(1 specimen).
300–200	1	3	(1 „ ).
400–300	0	3	
500–400	1	3	(1 „ ).
750–500	1	4	(1 „ ).

A range from the surface to below 500 fathoms in small numbers with no definite optimum is indicated by the above table.

Length, ♀, 3.7–4.3 mm.; ♂, 3.6–3.76 mm.

## EUAUGAPTILUS HECTICUS (Giesbr.).

*Distribution.*—

250–150 fms. (1 specimen, ♂).

350 fms. (1 „ ♀).

The coloured tufts at the ends of the antennules are still of a greenish-brown colour, as shown in Giesbrecht's coloured plate (1892), after twenty years preservation in formalin.

Length, ♀, 2.85 mm.; ♂, 2.4 mm.

## EUAUGAPTILUS PALUMBOI (Giesbr.).

*Distribution.*—

At 350 fms. in 1 out of 1 haul (1 specimen).

Between 300–200 fms. in 1 out of 3 hauls (1 specimen).

400–300	2	3 hauls, with 1.7	} Average specimens per 100-fathom haul.
500–400	2	1	
750–500	0	4	
1000–750	1	3 hauls (1 specimen, dead).	

Confined to layer between 300–500 fathoms, where it is frequent.  
Length, ♀, 2·04–2·3 mm.; ♂, 1·9 mm.

**EUAUGAPTILUS MAGNUS** (Wolfenden).

*Distribution.*—

At 250 fms. in 1 out of 2 hauls (1 specimen).

300            1            1 haul (1            „            ).

350            1            1 haul, with ·3 per cent. of total haul.

Between 400–300 fms. in 2 out of 3 hauls, with 1·3 per 100-fathom haul.

The range seems to be about 250–400 fathoms, the highest numbers being towards the lower limit.

Length, ♀, 6·96 mm.; ♂, 6·96 mm.

**EUAUGAPTILUS LATICEPS** (G. O. Sars).

*Augaptilus laticeps* Farran, 1908.

*Distribution.*—

Between 400–300 fms. (1 specimen, stage IV).

750–500            (1            „            ♀).

The larger specimen still retains its olive-green colour.

Length, ♀, 7·68 mm.; stage IV, 4·38 mm.

**EUAUGAPTILUS HUMILIS**, sp. n. (Pl. 10. figs. 4–10.)

*Description.*—Length, ♀, 1·54 mm.; cephalothorax 1·2 mm.; abdomen ·34 mm. Cephalothorax (Pl. 10. fig. 4) moderately elongate, oval. Cephalon slightly vaulted, uniformly rounded in dorsal and lateral view. No rostral filaments. Abdomen (Pl. 10. fig. 7) small, slightly more than one-fourth the length of the cephalothorax. Genital segment slightly swollen on the left side and a little longer than the combined length of the two segments, which are about equal in length. Furca about as long as the anal segment, with rami nearly twice as long as wide, ending squarely, with four subequal setæ, one on the outer edge and three terminal, right ramus being distinctly longer than the left.

Antennules broken at the tip, but evidently longer than the body by two or three joints.

Antennæ (Pl. 10. fig. 5) with *ri* about one and a half times *re*. *B* 2 longer than *re* and than 1st joint of *ri*.

Mandibles with well-developed 2-branched palp. Six long setæ on *rc*, six short ones on *ri*. Cutting edge (Pl. 10. fig. 6) with distal tooth long and curved, median tooth of moderate size and three small acicular proximal teeth.

First maxilla (Pl. 10. fig. 8) with narrow *li* 1, bearing eight strong spines about as long as the lobe, *li* 2 absent, *li* 3 with one seta, *ri* with 3+4 setæ, the distal four being on a separate joint, *re* with four long and three small terminal setæ, *le* with six strong setæ.

Second maxilla (Pl. 10. fig. 9) short. *B* 1 distinctly segmented with well-marked lobes. First lobe with three setæ, second and third with two each, fourth with three. *B* 2 comparatively long, with 2+2 setæ. Terminal joints very short, their setæ only slightly longer than those of the basal joints.

Maxillipedes (Pl. 10. fig. 10) of moderate length. *B* 1 with 1+3+3 short setæ. *B* 2 with 2+2 setæ. Terminal joints short, with slender setæ, equal in length to the two basal joints. There is no button-like armature on the setæ of the 2nd maxillæ or of the maxillipedes. Swimming feet with no distinctive features.

One specimen was taken in a horizontal net at 350 fathoms.

In some respects, especially in the form of the 1st and 2nd maxillæ, this species has appendages of a type resembling those of *Haloptilus* rather than *Augaptilus*, but in the form of the body and the 3-jointed abdomen it is clearly an *Augaptilus*.

#### CENTRAUGAPTILUS RATTRAYI (T. Scott).

##### *Distribution.*—

	By day in		By night in	
At 75 fms.	0 out of 3 hauls.		1 out of 8 hauls (1 specimen).	
100	6	12 hauls (7 specimens).	0	9 hauls.
Between 200–100 fms.	in 1 out of 6 hauls (1 specimen).			
300–200	1	3	(1 „ )	

It is not possible to say whether the daylight captures at 100 fathoms were due to an upward movement by day or to chance; the latter seems to be the more probable.

Length, ♀, 5.52–6.18 mm.

#### HETEROPTILUS ACUTILOBUS (Sars).

*Pontoptilus acutilobus* Sars, 1905.

Two specimens, one at 25 fathoms and one at 75 fathoms, were taken in the horizontal nets. Both were females, length 3.95 mm., and agreed fully with Sars's description (1905) and figures (1924).

#### PHYLLOPUS HELGÆ Farran.

##### *Distribution.*—

	By day in		By night in	
At 100 fms.	0 out of 12 hauls.		1 out of 9 hauls (1 specimen).	
At 150 fms.	in 1 out of 1 haul (1 specimen).			
200	0	2 hauls.		
250	2	2 hauls, with	.15	} Per cent. of average haul.
300	1	1	.37	
350	1	1	.3	

Between 150–50 fms. in 0 out of 1 haul.

200–100	1	6 hauls (1 specimen).	
250–150	0	3	
300–200	1	3 hauls, with	.7 } Specimens per
400–300	3	3	1 } 100-fathom haul.

The optimum range lies between 200 and 400 fathoms, with a very few occurrences above those limits.

Length, ♀, 2.28–2.46 mm.; ♂, 2.46 mm.

#### PHYLLOPUS IMPAR Farran.

##### *Distribution.*—

Between 400–300 fms. in 1 out of 3 hauls (1 specimen).

500–400	1	3 hauls, with	.7 per 100 fms.
750–500	1	4	(1 specimen).

The range of this species seems to begin at the lower limit of that of *P. Helge*.

Length, ♀, 2.64–2.88 mm.

#### CANDACIA ARMATA Boeck.

##### *Distribution.*—

By day in				By night in			
At	0 fms.	3 out of 9 hauls, with	.05 } Per	2 out of 4 hauls, with	.1 } Per		
	25	4 6	.33 } cent.	4 6	1.5 } cent.		
	50	6 7	.69 } of	3 5	.5 } of		
	75	3 3	1.4 } aver.	5 8	.7 } aver.		
	100	7 12	.3 } haul.	6 9	.2 } haul.		

At 150 fms. in 1 out of 1 haul, with .27 per cent.

200	0	2 hauls.
250	1	2 hauls (1 specimen).
300	1	1 (1 „ ).

This is a markedly epiplanktonic form with no noticeable difference between its day and night distribution and a maximum at 75 fathoms. It was not recognized below 300 fathoms, though possibly some immature specimens may have been overlooked.

Length, ♀, 2.4–2.64 mm.; ♂, 2.48–2.54 mm.

#### CANDACIA ROTUNDATA Wolfenden.

*Distribution.*—One specimen, a female, was taken in a vertical haul between 400 and 300 fathoms. This scarcity is noteworthy, considering that it is not uncommon in the Atlantic off the west coast of Ireland.

Length, ♀, 3.44 mm.

*CANDACIA TENUIMANA* Giesbr.*Candacia gracilimana* Farran, 1908.*Distribution.*—

By day in				By night in			
At 50 fms.	} 0 out of 23 hauls.			2 out of 6 hauls, with	·07	} Per cent. of average haul.	
75				4	8		·03
100				4	9		·1

At 300 fms. in 1 out of 1 haul (1 specimen).  
 350            1            1            (1 „ ).

Between 200–100 fms. in 1 out of 6 hauls (1 specimen).  
 250–150            1            3 hauls, with 1 } Specimens per  
 300–200            2            3            1 } 100-fathom haul.

Absent from the epiplankton by day, but occurring singly or in very small numbers between 50 and 100 fathoms by night. The range extends down to 350 fathoms.

Length, ♀, 2·28–2·34 mm.; ♂, 2·16 mm.

The male of this species was formerly described by me from the west coast of Ireland under the name of *C. gracilimana*. Though the female is slightly larger than the specimen described by Giesbrecht (1892) from the Mediterranean, length 2·05 mm., it can readily be identified by the form of the 5th foot. The small projection on the left side of the genital segment of the female which Giesbrecht gives as a distinguishing feature is not easy to make out.

*ANOMALOCERA PATERSONI* Templ.*Distribution.*—

By day in				By night in			
At 0 fms.	2 out of 9 hauls, with	·2	} Per cent. of aver. haul.	2 out of 4 hauls, with	·09	} Per cent. of aver. haul.	
25	3	6		2	6		·12
50	} 0	10		0	14		0
75							
100		12		2	9		·01

The specimens in the 100-fathom nets may possibly have been taken while these nets were being hauled to the surface, but they occurred more often than might have been expected if this were the case.

Length, ♂, 3·12–3·18 mm.

*ACARTIA CLAUSI* Giesbr.*Distribution.*—

By day in				By night in			
At 0 fms. (Net 180)	6 out of 6 hauls, with	8·5	} Per cent. of aver. haul.	3 out of 3 hauls, with	16	} Per cent. of aver. haul.	
„ (Net 60)	9	9		4	4		15·5
25	6	6		6	6		6·6
50	7	7		5	5		1
75	3	3		9	9		7·5
100	12	12		9	9		1·1

At 150 fms. in 1 out of 1 haul, with	·4
200	1 2 ·05
250	1 2 ·08
300	1 2 0
350	1 1 ·2
Between 150- 50 fms. in 0 out of 1 haul.	
200- 100	4 6 hauls, with 3
250- 150	3 3 5·7
300- 200	2 3 1·7
400- 300	1 3 hauls (1 specimen).
500- 400	2 4 hauls, with 1·3
750- 500	2 4 ·9
1000- 750	3 3 1·2
1250-1000	0 2 0
1500-1250	1 1 1·6

This is mainly an epiplanktonic species, the few specimens from below 300 fathoms being probably sinking or strays. There is a wide difference in the percentages present in different townettings at the same level, and possibly there are not sufficient gatherings to smooth out the apparent variations due to this. There seems, however, to be grounds for saying that by day the maximum was at 25 fathoms and by night at the surface.

Length, ♀, 1·2 mm.; ♂, 1·08-1·18 mm.

#### MORMONILLA PHASMA Giesbr.

##### *Distribution.*—

At 350 fms. in 1 out of 1 haul, with ·4 per cent.

Between 400-300 fms. in 1 out of 3 hauls (1 specimen).	
500-400	1 3 hauls, with 1 } Average specimens
750-500	3 4 ·3 } per 100-fathom haul.
1000-750	1 3 hauls (1 specimen).

On account of its small size and very slender form it is clear that the nets used do not give any indication of the numbers actually present. Its distribution is evidently from 350 to below 750 fathoms.

Length, ♀, 1·32-1·5 mm. The furca in these specimens is divided by the outer edge seta in the proportion 10 : 20-10 : 24. This differs a little from the original description of Giesbrecht (1892), which gives the proportion as 10 : 17.

#### MORMONILLA MINOR Giesbr.

Between 500-400 fms. in 1 out of 3 hauls (2 specimens).

#### OITHONA SIMILIS Claus.

##### *Distribution.*—

Net 180.	By day in		By night in		Per cent.	
At 0 fms.	6 out of 6 hauls, with 46		3 out of 3 hauls, with 13·5			
Nets 60 & 65.						
0 fms.	7	7	·8	2	4	2·2
25	4	6	1·1	6	6	1·7
50	3	7	·3	2	5	·3
75	3	3	·1	7	8	·3
100	9	12	·1	6	9	·1

At 150 } fms. in 0 out of 3 hauls.  
200 }

250           1           2 hauls, with 1 per cent.  
300           0           1  
350           1           1           (1 specimen).

Between 150- 50 fms. in 0 out of 1 haul.

200- 100           1           6 hauls (2 specimens).  
250- 150           2           3           (2           "           ).  
300- 200           2           3 hauls, with 2 per 100-fathom haul.  
400- 300           1           3           (2 specimens).  
500- 400           0           3  
750- 500           1           4           (1 specimen).  
1000- 750           1           3           (2 specimens).  
1250-1000           2           2 hauls, with .6 per 100-fathom haul.

On account of its small size it is certain that none of the nets, except the fine-meshed (180) surface net, took more than a very small proportion of the numbers present. The optimum range seems to be 0-25 fathoms, but occasional specimens are met with, usually singly, down to below 1000 fathoms. The high percentage of 46 for daylight hauls with the 180-mesh net shows that it is really a very abundant species at or near the surface, probably concentrating in the surface layer during daylight.

Length, ♀, .81-.84 mm.

#### OITHONA ATLANTICA Farran.

*Oithona atlantica* Farran, 1908.

*Oithona spinirostris* G. O. Sars, 1913.

*Oithona atlantica* Rosendorn, 1917.

#### Distribution.—

Net 180.                           By day in                           By night in  
At 0 fms. 1 out of 6 hauls (1 specimen).           0 out of 3 hauls.

Nets 60 & 61.

0 fms.	5 out of 9 hauls, with 1.3	} Per cent. of average haul.	1 out of 4 hauls, with .5	} Per cent. of average haul.
25	2           6           .1		5           6           .3	
50	6           7           2.4		4           5           .9	
75	3           3           9.5		8           8           3.1	
100	12           12           8.4		9           9           4.6	

At 150 fms. in 1 out of 1 haul, with 4	} Per cent. of average haul.
200           1           2           1.8	
250           2           2           3.3	
300           1           1           3.1	
350           1           1           2.2	

Between 150- 50 fms. in 1 out of 1 haul, with 47	} Average specimens per 100-fathom haul.
200-100           6           6           10	
250-150           3           3           2	
300-200           0           3           0	
400-300           3           3           1.7	
500-400           3           3           2.3	
750-500           4           4           .7	
1000-750           3           3           2.7	



Contrary to what is found in the case of *O. similis*, this species increases regularly to a maximum between 75 and 200 fathoms and, allowing for the differences of mesh in the nets used, continued downwards in moderate and fairly uniform numbers to about 1000 fathoms.

Length, ♀, 1.08–1.2 mm.

The probability that this is the species which Claus described under the name of *O. spinirostris* is very strong, and Sars has adopted that name, but Rosendorn regards the question as open. If the differences between this species and *O. plumifera* are to be regarded as varietal, as Sars seems to imply in his "Monaco" list (1916), *O. plumifera* must stand as the type and not as the variety. Rosendorn, however, separates the two forms, and no trace of "plumes" was seen on any of the 'Research' specimens.

#### OITHONA SETIGERA Dana.

*Oithona pelagica* Farran, 1908 *b*.

##### *Distribution.*—

By day in				By night in			
At 0 fms.	2 out of 9 hauls,	with 1.8	Per	0 out of 4 hauls.			Per
25	0	6	0	0	6		cent.
50	0	7	0	0	5		of
75	2	3	1.5	6	8 hauls, with .1		aver.
100	12	12	.6	7	9	.4	haul.

At 150 fms. in 1 out of 1 haul, with 3.6			
200	2	2	3.2
250	2	2	3.0
300	1	1	1.1
350	1	1	.9

Per cent.  
of average  
haul.

Between 150–50 fms. in 1 out of 1 haul, with 5			
200–100	6	6	9
250–150	3	3	13
300–200	1	3	4.3
400–300	0	3	0
500–400	1	3 hauls (1 specimen).	
750–500	0	4	0
1000–750	1	3	(1 specimen).

Average  
specimens  
per 100-  
fathom haul.

Above 100 fathoms the distribution resembles that of *O. atlantica*, with about one-tenth of its abundance. From 100 to 300 fathoms the numbers of the two species are about equal, but below 300 fathoms *O. setigera* is almost entirely absent.

Length, ♀, 1.4–1.59 mm.

I no longer think that the name *O. pelagica*, which I proposed (1908 *b*) for the N.E. Atlantic form of *O. setigera* on account of the absence of thickened setæ on the swimming feet, can be maintained. Rosendorn has shown that in this, as in other respects, *O. setigera* is very variable.

**PONTÆCIELLA ABYSSICOLA (T. Scott).***Artotrogus abyssicolus* T. Scott.*Pontæciella abyssicola* Giesbrecht.*Distribution.*—

At 100 fms. (1 specimen, ♀).

Between 200–100 fms. (1 specimen, ♀).

750–500 (1 „ ♀).

Length, ♀, 1.15 mm.

**RATANIA ATLANTICA, sp. n. (Pl. 9. fig. 18; Pl. 10. figs. 11, 12.)**

*Description.*—Length, ♀, 2.34 mm.; cephalothorax 1.62 mm.; abdomen .72 mm. Resembles Giesbrecht's (1892) figure of *R. flava* in dorsal view (Pl. 10. fig. 11), but the cephalon is not so broad, the outline of the cephalothorax more oval, and the abdomen proportionately a little shorter, less than half as long as the cephalothorax. The furcal rami are slightly longer, being about twice as long as wide. The antennules (Pl. 10. fig. 12) are 7-jointed, with three joints corresponding to the 3rd joint of *R. flava*; 7th joint equals combined length of joints 4–6, and is thus proportionately longer than in *R. flava*. Antenna and mouth-parts similar to those of *R. flava*. Swimming feet agree in jointing, setæ, and general appearance to those of *R. flava*, but *re* 3 of 1st foot (Pl. 9. fig. 18) is narrower than is shown in Giesbrecht's figure, and *ri* 3 of the 4th foot has the outer edge seta at the distal third of the outer margin instead of about in the middle of the outer margin. 5th foot as in *R. flava*, but slightly narrower.

There seems to be sufficient reason for separating this species from *R. flava* on account of its larger size and the different jointing of the antennules. A specimen from the west coast of Ireland, taken in 1905 in a tow-net at 500 fathoms, showed similar characters, but only measured 1.9 mm.

*Distribution.*—One specimen in a vertical haul from 1000–750 fathoms.

**ONCÆA CONIFERA Giesbr.***Distribution.*—

By day in				By night in			
At 0 fms.	3 out of 9 hauls,	with 1.9		Per cent.	0 out of 4 hauls.		Per cent.
25	0	6	0	of	4	6 hauls, with .1	of
50	1	7	.03	aver.	3	5	.09
75	1	3	.36	haul.	7	8	.75
100	11	12	.33		6	9	.07
At 150 fms. in 1 out of 1 haul, with .3							
200	1	2	.2	Per cent.			
250	1	2	(1 spec.)	of average			
300	1	1 haul, with .5		haul.			
350	1	1	.7				

Between 150- 50 fms. in 1 out of 1 haul, with 3				
200- 100	6	6	2.2	Average specimens per 100-fathom haul.
250- 150	1	3	(1 spec.)	
300- 200	1	3 hauls, with 1		
400- 300	3	3	6.7	
500- 400	3	3	19	
750- 500	4	4	5.1	
1000- 750	3	3	28	
1250-1000	2	2	7.2	
1500-1250	1	1	8	
2000-1500	1	1	1	

The optimum for this species clearly extends from 400 to 1000 fathoms, and, considering that it probably passed easily through the meshes of the vertical nets, it must be plentiful in that region. It is one of the few species which was found alive below 1500 fathoms. In the epiplankton above 100 fathoms it is scarce, and occurred more often by night than by day.

Length, ♀, 1.2-1.38 mm.

#### ONCÆA MEDITERRANEA Claus.

##### *Distribution.*—

	By day in		By night in		
At 50 fms. } 0 out of 10 hauls.			2 out of 5 hauls, with .01		Per cent. of average haul.
75 } 6			2	8	
100 } 12 hauls, with .08 %.			3	9	

Between 200-100 fms. (1 specimen).

500-500 (1 „ ).

The numbers taken are so small that it is not possible to say more than that it seems to be principally an epiplanktonic form occurring in small numbers at 100 fathoms by day and sometimes rising to 50 fathoms by night.

Length, ♀, 1.3-1.6 mm. ; ♂, 1.02-1.12 mm.

#### ONCÆA MEDIA Giesbr.

*Distribution.*—This generally distributed oceanic species was only taken when nets of 180 or 65 mesh were used.

At 0 fms. (180 mesh) in 3 out of 9 hauls (4 specimens).

25 ( 65 „ ) 3 8 (3 „ ).

75 ( 65 „ ) 4 8 hauls, with .05 per cent. of average haul.

Length, ♀, .72-.79 mm.

#### ONCÆA SUBTILIS (Giesbr.).

##### *Distribution.*—

At 0 fms. (180 mesh) in 2 out of 9 hauls (3 specimens).

0 ( 60 „ ) 1 13 (1 specimen).

This is probably a surface form. It is too small to be taken except by the 180 mesh nets.

*CONÆA RAPAX* Giesbr.*Distribution.*—

Between 400–300 fms. in 1 out of 3 hauls (1 specimen).

500–400	1	3	(1	„	).
750–500	2	4	hauls, with	·5	}
1000–750	2	3		·27	} Average specimens per 100-fathom haul.

A fairly uniform distribution from 300 to about 1000 fathoms is indicated by the records. Owing to its small size, only a very small proportion of the numbers present can have been captured.

Length, ♀, 1·12–1·14 mm. ; ♂, 1·0–1·02 mm.

*LUBBOOKIA ACULEATA* Giesbr.

*Distribution.*—One specimen, ♀, length 2·28 mm., was taken in a horizontal net at 50 fathoms. Already recorded by Giesbrecht from the Mediterranean, and by Wolfenden and Sars from the North Atlantic.

*SAPPHIRINA NIGROMACULATA* Claus. (Pl. 9. fig. 17.)*Distribution.*—

At 0 fms. in 1 out of 13 hauls (1 specimen).

25	1	12	(1	„	).
50	2	12	hauls, with	·01	}
100	2	21		·01	} Per cent. of average haul.

Ten specimens in all were examined, 3 ♂ ♂ and 7 ♀ ♀. There is some evidence of an irregular horizontal distribution, as these records came from Station 30 and two from Station 21 in two successive hauls.

Length, ♀, 1·8–1·98 mm. ; ♂, 2·16–2·28 mm. From Giesbrecht's (1892) diagnostic table these specimens can be identified as *S. nigromaculata*, with which in size and in the form of the appendages they agree; the females, however, differ from Giesbrecht's figure in the form of the thorax, the second segment being noticeably wider than the first or third, as is seen in *S. soarlatata*, and in the slightly longer abdomen. Possibly these differences may be due to different methods of preservation. The males retained a brilliant iridescence of the furca after over twenty years' preservation in formalin.

*CORINA GRANULOSA* Giesbr.

Two specimens, both males, were taken, one at the surface, the other at 25 fathoms.

Length, ♂, ·68–·8 mm.

? *CORYCÆUS ANGLICUS* Lubb.

Two specimens were taken at the surface, one ♂ and one ♀.

Length, ♀, 1·1 mm. ; ♂, ·88 mm.

The female differed from *C. anglicus* in some small points; the genital segment was about  $1\frac{1}{2}$  times as long as its basal width instead of  $1\frac{1}{4}$  times, and total length of the abdomen was contained about  $2\frac{1}{2}$  times in the total length of the animal instead of three times, as is usual in *C. anglicus*. The appendages of the female agreed fairly well with those of *C. anglicus*. The 2nd antenna had only one distal tooth on the inner margin of the 2nd joint.

*CORYCÆUS FURCIFER* Claus.*Distribution.*—

At 0 fms. in 0 out of 13 hauls.

25            2            12 hauls (2 specimens).

50            1            12            (1 specimen).

75            2            11            (3 specimens).

100          10          21 hauls, with .09 per cent. by day and .04 per cent. by night.

At 150 fms. }

200            } in 0 out of 6 hauls.

250

300

300            1            1 haul (1 specimen).

This is evidently a species of the lower epiplankton with no noticeable difference between day and night distribution. The specimen from 350 fathoms may have been taken during the hauling of the net.

Length, ♀, 1.76–1.92 mm. ; ♂, 1.2–1.3 mm.

*MICROSETELLA ROSEA* Dana.*Distribution.*—

At 0 fms. in 1 haul (2 specimens).

100           1           (1 specimen).

350           1           (1 „ ).

Owing to the small size of this and the following species, nothing can be deduced from their absence from most of the hauls in the collection.

Length, ♀, .83 mm.

*MICROSETELLA NORVEGICA* Boeck.*Distribution.*—

At 0 fms. in 1 haul (1 specimen).

25            1            ( „ ).

Between 200–100 fms. in 1 haul (1 specimen).

1000–750      1            (1 „ ).

Length, ♀, .57 mm.

*BATHYIDIA*, n. g.

Agrees with *Idya* in general form and structure of the appendages, except that the cephalon is longer in proportion to the total length, the furcal rami are much longer than wide, and the first foot has three long setæ on the 3rd joint of the endopodite and is without lamellar wings on the setæ of the exopodite.

*BATHYIDIA REMOTA*, sp. n. (Pl. 10. figs. 13–17.)

*Description.*—Length, ♀, 1.48 mm. ; cephalothorax 1.0 mm. ; abdomen .48 mm. The thoracic segments were injured and imperfect ; possibly they were longer than is shown in the figure (Pl. 10. fig. 13). The abdomen is about two-thirds of the length of the cephalon, genital segment with a faintly marked segmentation and twice as long as the two following segments

together, anal segment very short and in dorsal view almost covered by the preceding segment, but in ventral view about half as long as it. The furca (Pl. 10. fig. 15) is about three times as long as wide and equal in length to the width of the anal segment, with a long outer edge seta arising slightly in front of the middle of the outer edge, four terminal setæ, the outermost short and forked, the outer branch being the shorter, the next about half as long as the furca, and the two innermost broken in the single specimen. There is one small seta on the dorsal face of the furca nearer the inner than the outer edge, and on the ventral face an oblique row of spinules in front of the base of the outer edge seta.

Antennules (Pl. 10. fig. 14) about half as long as the cephalothorax, 8 jointed. Length of joints in .01 mm.:—

No. ....	1	2	3	4	5	6	7	8
Size ... ..	8	10	8	7	3	4	2	8

Antennæ as in *Idya*; *re* with six terminal setæ, the two outermost being much thicker than the rest. Mandible not examined. 1st and 2nd maxillæ and maxillipede as in *Idya*, with no characteristic features. 1st foot (Pl. 10. fig. 16) with *ri* about  $1\frac{1}{2}$  times as long as *re*, 1st and 2nd joints each with a well-developed *si*, 3rd joint with three well-developed terminal setæ, the outermost being the longest, *re* 1 with 1 *se*, *re* 2 with 1 *se* and 1 *si*, *re* 3 with six setæ, which are without the lamellar wings found in *Idya*. 2nd, 3rd, and 4th feet, as in *Idya*, with no distinctive characters. 5th feet (Pl. 10. fig. 17) long and narrow, parallel-sided, nearly as long as the genital segment.

*Distribution*.—One specimen in a vertical haul (32*k*) between 1000–750 fathoms.

#### CLYTEMNESTRA ROSTRATA Brady.

One specimen was taken at 50 fathoms and two at 75 fathoms.

Length, ♀, .95–1.08 mm.

#### CLYTEMNESTRA SCUTELLATA Dana.

One specimen, ♀, length 1.2 mm., at 75 fathoms.

#### ÆGISTHUS MUCRONATUS Giesbr.

##### *Distribution*.—

At 250 fms. in 2 out of 2 hauls (2 specimens).

300	1	1 haul, with 1.05	} Per cent. of average haul.
350	1	1	

Between 200–100 fms. in 1 out of 6 hauls (1 specimen).

250–150	1	1	(1	”	).	} Average specimens per 100-fathom haul.
300–200	2	3 hauls, with 2.7				
400–300	1	3		4		
500–400	2	3			.7	
750–500	2	4			.2	
1000–750	1	3			.5	

The optimum clearly lies at about 300–400 fathoms, with the range extending upwards to about 150 fathoms and downwards to below 750 with very small numbers.

Length, ♀, 2·16–2·28 mm. Except for a few young stages all the specimens were adult females.

*ÆGISTHUS ACULEATUS* Giesbr.

One specimen, ♂, was taken in a vertical haul from 1000 to 750 fathoms. Length, ♂, 1·28 mm.

*ÆGISTHUS DUBIUS* G. O. Sars.

*Distribution.*—

At 250 fms. in 2 out of 2 hauls, with ·2 per cent. of average haul.

300	1	1 haul (1 specimen).
350	1	1 (2 specimens).

Between 300–200 fms. in 2 out of 3 hauls (2 specimens).

400–300	}	0	6	
500–400				
750–500		1	4	(1 specimen).

The distribution is, on a smaller scale, very similar to that of *Ægisthus mucronatus*. All the specimens were males.

Length (without furca), ♂, 1·56–1·7 mm. The type described by Sars (1916), also a male, only measured 1·1 mm. In the only complete specimen, length 1·6 mm., the unbroken furca measured 6·7 mm., very little more than four times the body-length instead of five times as in Sars's description, but the appendages and form agreed so closely with the description and figures that I do not think that the differences are specific. There is a minute sixth pair of legs, 1-jointed with one *se* and one *st*, which Sars does not mention in his description.

The facts that only the male of this species has been found and only the female of *A. mucronatus*, and that *A. mucronatus* ♂ was found in every gathering in which *A. dubius* occurred, raises a strong suspicion that *A. dubius* may be the male of *A. mucronatus*. Sars on consideration has rejected this view, but the question must still be regarded as open. Against it may be said that T. Scott (1894) has recorded the male of *A. mucronatus*, under the name of *A. longirostris*, from the Gulf of Guinea, without mention of the absence of a cephalic spine. This argument from his silence is not conclusive, and the appendages of the male which he has figured (antennule, 2nd maxilla, and 5th feet) agree closely with those of *A. dubius*, except that he shows the outer terminal spine of the 5th foot as arising slightly in advance of the inner instead of beside it as in *A. mucronatus* ♀ and *A. dubius* ♂.

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## EXPLANATION OF THE PLATES.

## PLATE 5.

- Fig. 1. *Calocalanus contractus* ♀, dorsal view. × 72.  
 2. " " lateral view. × 72.  
 3. " " 5th foot. × 248.  
 4. " " abdomen, dorsal. × 168.  
 5. *Calocalanus styliremis* ♀, dorsal view. × 63.  
 6. " " abdomen, dorsal. × 186.  
 7. *Calocalanus tenuis* ♀, dorsal view. × 64.  
 8. " " lateral view. × 64.  
 9. " " 1st foot. × 280.  
 10. " " 2nd foot. × 280.  
 11. " " 4th foot. × 280.  
 12. " " 5th foot. × 280.

## PLATE 6.

- Fig. 1. *Clausocalanus arcuicornis* ♀, lateral view. × 35.  
 2. " " furca. × 143.  
 3. " " 5th foot. × 143.  
 4. *Clausocalanus perygens* ♀, lateral view. × 57.  
 5. " " furca. × 297.  
 6. " " 5th foot. × 297.  
 7. *Clausocalanus paululus* ♀, lateral view. × 67.  
 8. " " abdomen, lateral. × 95.  
 9. " " 3rd foot. × 297.  
 10. " " 2nd foot, b2 and ri. × 297.  
 11. " " 5th foot. × 297.  
 12. " " furca. × 210.  
 13. *Monacilla tenera* ♀, lateral view. × 37.  
 14. " " dorsal view. × 37.

## PLATE 7.

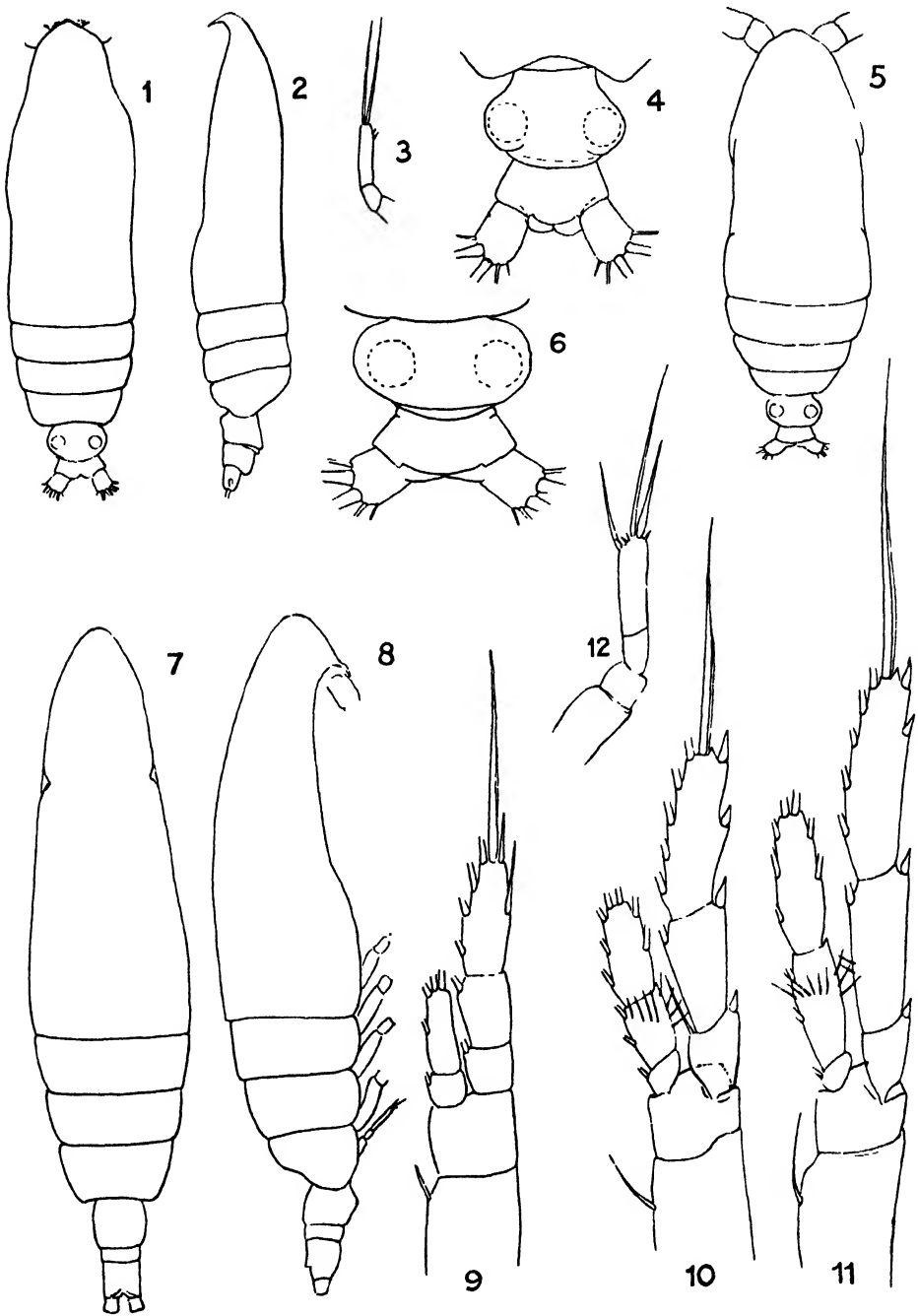
- Fig. 1. *Scolecithrix curta* ♀, lateral view. × 65.  
 2. " " dorsal view. × 65.  
 3. " " 1st foot. × 212.  
 4. " " 1st foot, *ri* (another specimen). × 212.  
 5. " " 2nd foot. × 208.  
 6. " " 3rd foot. × 208.  
 7. *Scolecithrix Fowleri* ♀, lateral view. × 36.  
 8. " " dorsal view. × 29.  
 9. " " antennule. × 128.  
 10. " " antenna. × 86.  
 11. " " 1st maxilla. × 116.  
 12. " " maxillipede. × 116.

## PLATE 8.

- Fig. 1. *Scolecithrix Fowleri* ♀, 2nd foot. × 86.  
 2. " " 3rd foot. × 86.  
 3. " " 5th foot. × 229.  
 4. *Scolecithrix valens* ♀, 5th foot. × 162.  
 5. *Scolecithrix laminata* ♀, lateral view. × 35.  
 6. " " 2nd foot. × 81.  
 7. " " 3rd foot. × 81.  
 8. " " 5th foot. × 255.  
 9. *Scolecithrix falcifer* ♀, dorsal view. × 32.  
 10. " " abdomen. × 51.  
 11. " " antenna. × 64.  
 12. " " 2nd foot. × 64.  
 13. " " 3rd foot. × 64.  
 14. " " 5th foot. × 170.

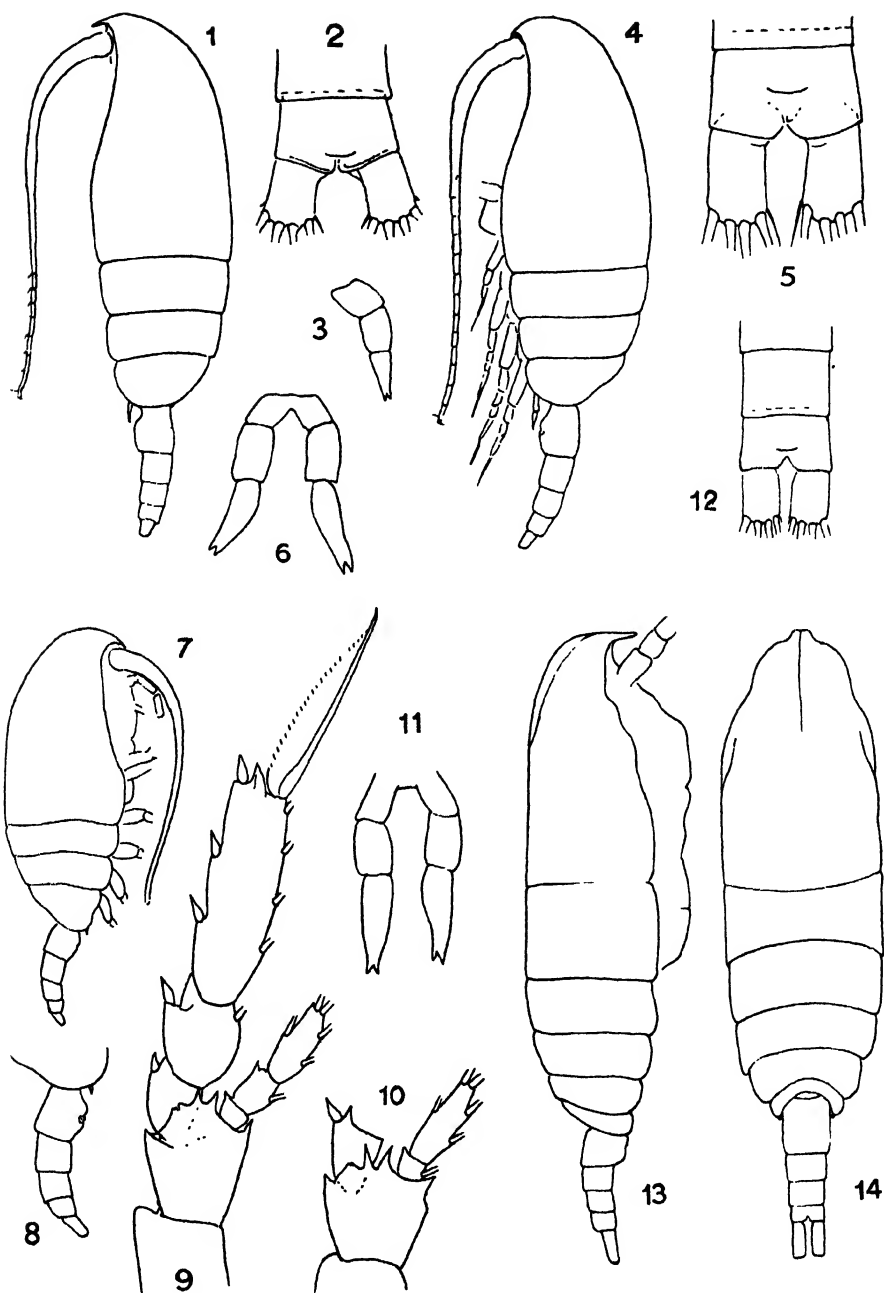
## PLATE 9.

- Fig. 1. *Lucicutia flavicornis* ♀, lateral view. × 44.  
 2. " " furca. × 91.  
 3. " " 1st foot, 2 *b*. × 168.  
 4. *Lucicutia gemina* ♀, lateral view. × 42.  
 5. " " furca. × 77.  
 6. " " 1st foot, 2 *b*. × 168.  
 7. " " 2nd foot. × 110.  
 8. " " 5th foot. × 110.  
 9. *Lucicutia simulans* ♀, 1st foot. × 68.  
 10. " " 5th foot. × 72.  
 11. " " 2nd foot, *rs*. × 72.  
 12. " " ♂, right 5th foot. × 78.  
 13. " " left 5th foot. × 78.  
 14. *Haloptilus angusticeps* ♀, mandible, cutting edge. × 87.  
 15. *Haloptilus bulliceps*, stage IV, antenna. × 42.  
 16. " " " mandible, cutting edge. × 87.  
 17. *Sapphirina nigromaculata* ♀, dorsal view. × 19.  
 18. *Ratania atlantica* ♀, 1st foot. × 78.



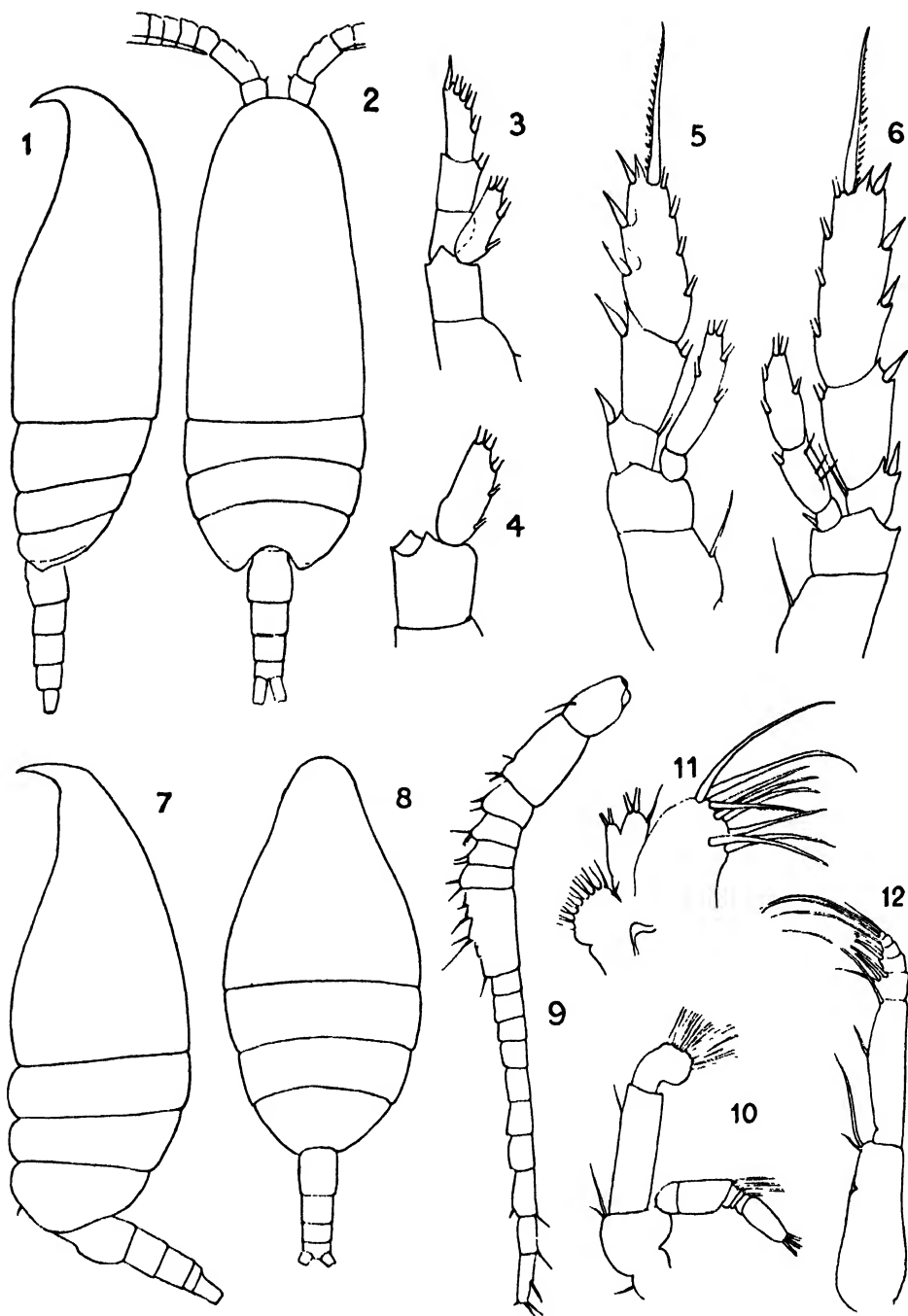
BISCAYAN COPEPODA.





**BISCAYAN COPEPODA.**

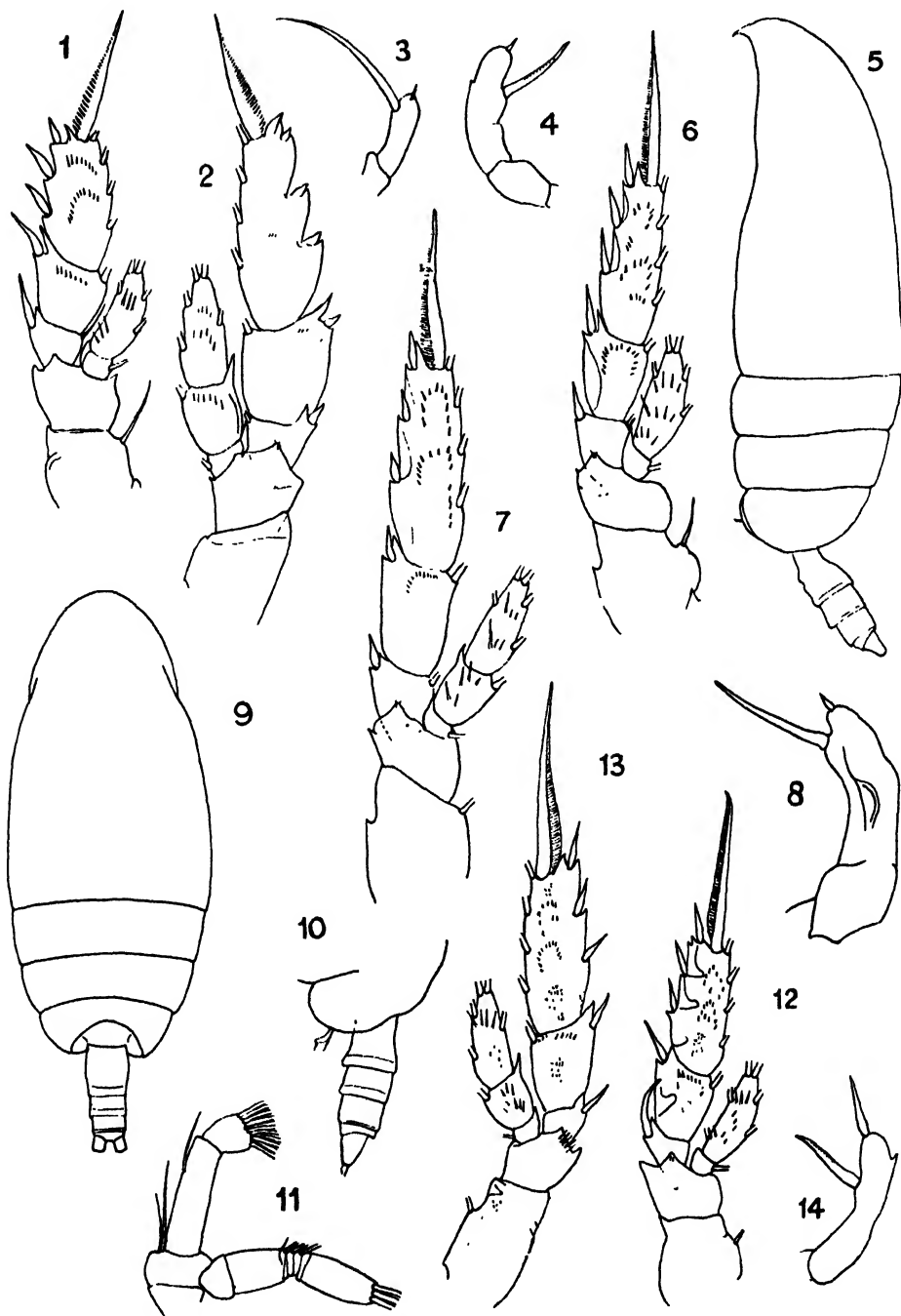




**BISCAYAN COPEPODA.**

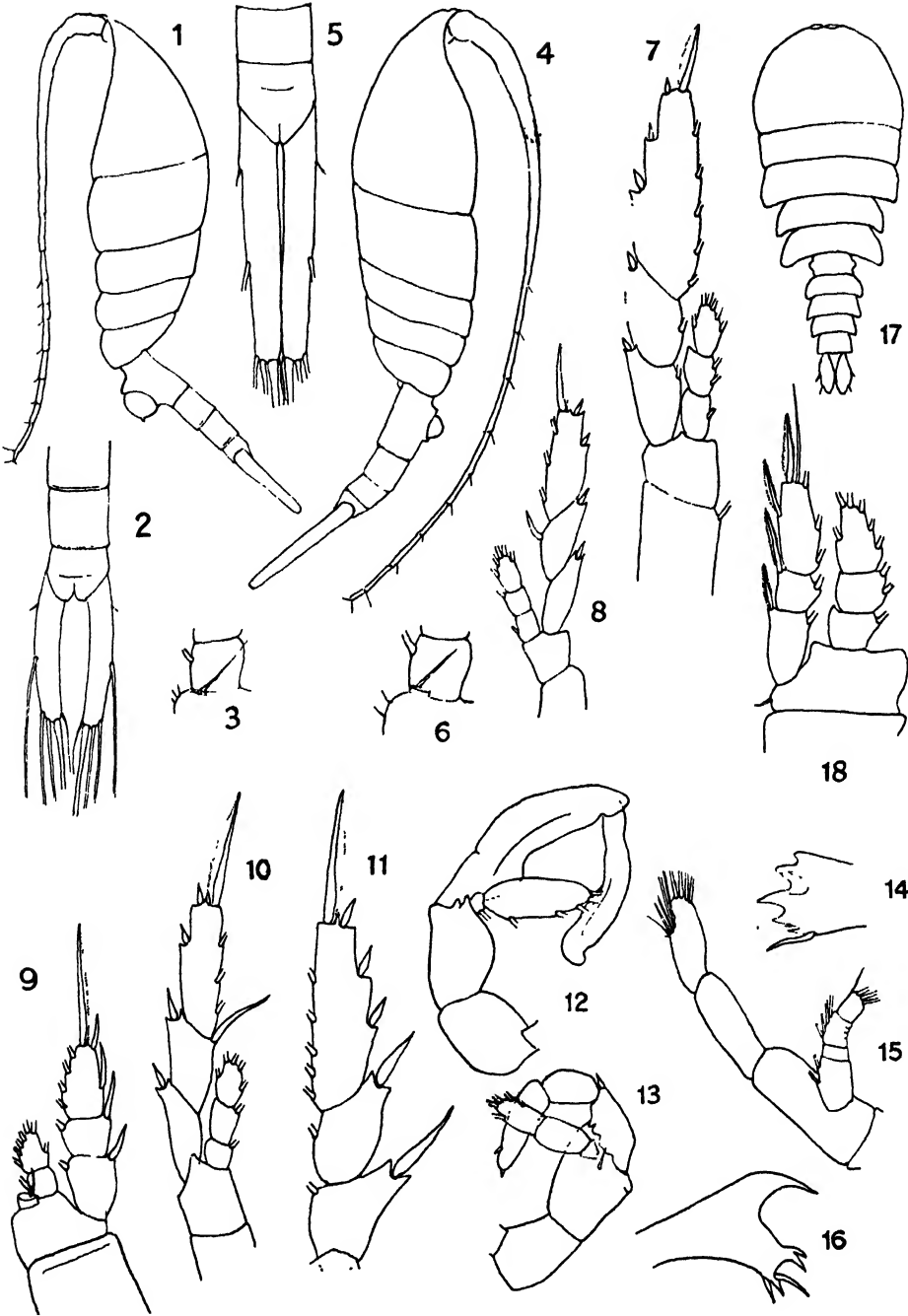






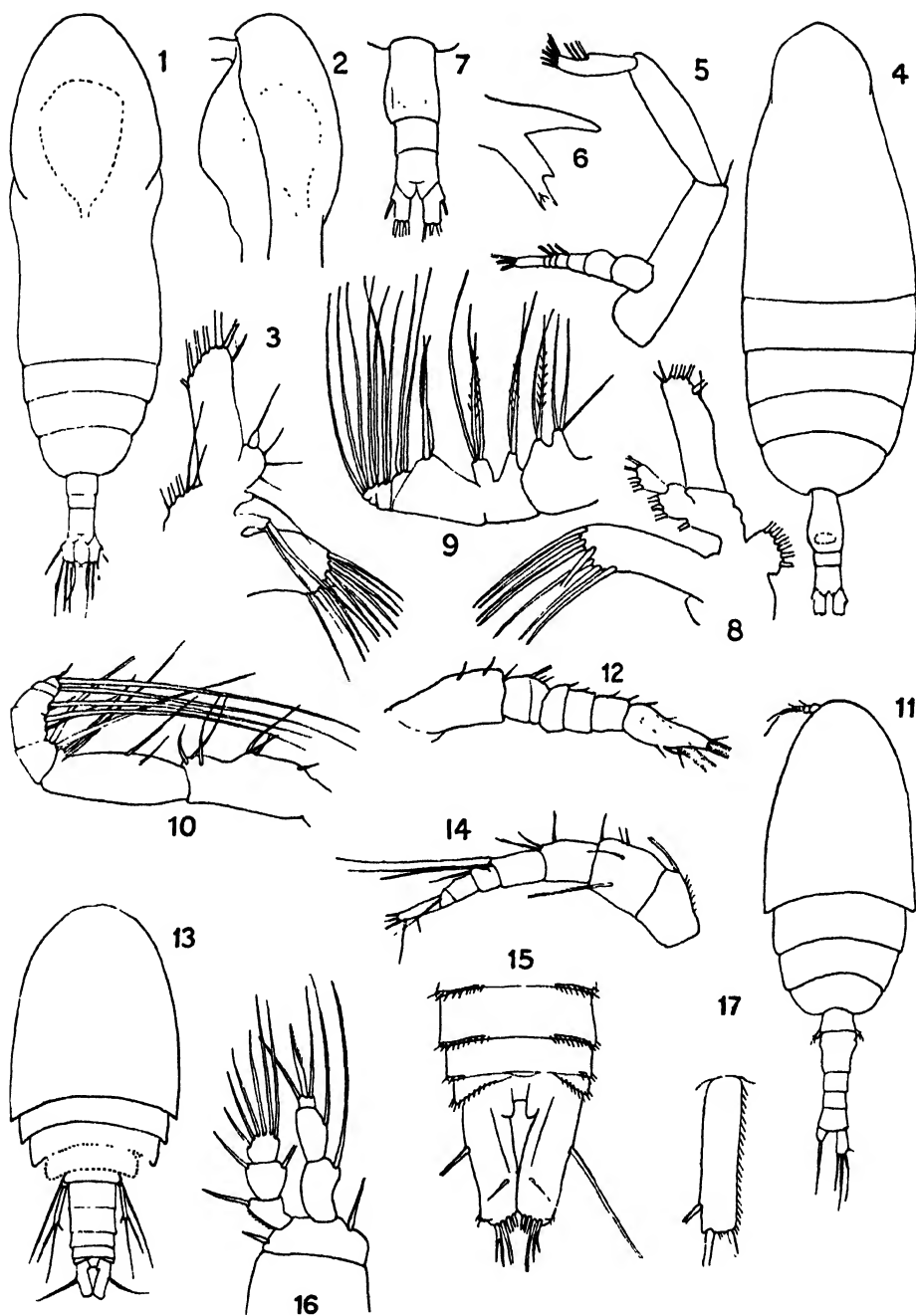
BISCAYAN COPEPODA.





BISCAYAN COPEPODA.





**BISCAYAN COPEPODA.**



## PLATE 10.

- Fig. 1. *Haloptilus bulliceps*, stage IV, dorsal view.  $\times 17$ .  
 2. " " " cephalon, lateral.  $\times 17$ .  
 3. " " " 1st maxilla.  $\times 61$ .  
 4. *Euaugaptilus humilis* ♀, dorsal view.  $\times 44$ .  
 5. " " antenna.  $\times 109$ .  
 6. " " mandible, cutting edge.  $\times 175$ .  
 7. " " abdomen.  $\times 63$ .  
 8. " " 1st maxilla.  $\times 175$ .  
 9. " " 2nd maxilla.  $\times 100$ .  
 10. " " maxillipede.  $\times 97$ .  
 11. *Ratania atlantica* ♀, dorsal view.  $\times 24$ .  
 12. " " antennule.  $\times 76$ .  
 13. *Bathyidia remota* ♀, dorsal view.  $\times 31$ .  
 14. " " antennule.  $\times 84$ .  
 15. " " furca.  $\times 104$ .  
 16. " " 1st foot.  $\times 82$ .  
 17. " " 5th foot.  $\times 133$ .





<i>Centropages typicus</i> .....	270	33	44	270	66	145	2	4	6	143	2	4	176	24	15	275	232	46	1
<i>Mesocyclops leucae</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>M. princeps</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>M. tenuis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>M. brevicornis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Pleuromma robusta</i> .....	7	3	9	33	25	180	51	56	44	140	51	46	194	163	17	154	19	6	4
<i>P. abdominalis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>P. spinica</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>P. gracilis</i> .....	26	...	23	44	13	67	580	318	9	125	580	108	34	...	...	...	...	...	...
<i>Lucicutia flavicornis</i> .....	1	3	1	5	1	7	1	3	5	3	1	2	...	...	...	...	...	...	...
<i>L. gemma</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>L. magna</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>L. curia</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Haemorhabdus alysioides</i> .....	2	3	3	12	6	9	...	7	2	11	4	8	...	...	...	...	...	...	...
<i>H. norvegicus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. brevicornis</i> .....	6	1	3	7	1	3	2	1	3	...	2	4	3	...	...	...	...	...	...
<i>H. spiniferus</i> .....	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. papilliger</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. longicornis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. brevicornis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. eipera</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. longicornis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Haloptilus acutifrons</i> .....	3	2	1	1	16	16	4	6	4	3	4	3	...	...	...	...	...	...	...
<i>H. longicornis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>H. belliceps</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Aspeytilus longicaudatus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Thaumatopeltis palumbus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>E. hecticus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>E. mugensis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>E. laticeps</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Centropages Raittrayi</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Phyllopus Helge</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>P. impar</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Caudeata rotundata</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>G. tenuimana</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Acartia Clavata</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Monomilla plasma</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Oithona similis</i> .....	47	3	6	21	1	23	2	5	6	1	1	2	5	1	...	...	...	...	...
<i>O. atlantica</i> .....	5	...	3	16	3	18	22	9	5	14	...	4	13	...	...	...	...	...	...
<i>O. setigera</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Pontastella abyssicola</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Oncaea confusa</i> .....	3	1	1	1	1	1	...	1	6	1	...	...	4	...	...	...	...	...	...
<i>O. mediterranea</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Oncaea rapax</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Microsetella norvegica</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Agathus mucronatus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>A. dubius</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total number of species .....	23	18	24	22	25	36	35	33	212	733	31	32	40	22	11	42	34	26	...
Total number of specimens .....	515	82	156	561	233	568	821	212	733	1162	449	361	684	361	55	649	365	104	...

TABLE II.

Vertical Hauls between 400 and 2000 fms.	500-400 fms.			750-500 fms.			1000-750 fms.			1250-1000 fms.		1500-1250 fms.		1500-1500 fms.	
	21 m	35 A	35 f	22 b	30 k	34 e	34 f	23 a	31 d	32 k	27 b	31 c	30 i	26 d	36
No. of Haul.....	36	45	45	36	45	45	45	36	45	45	45	45	45	36	36
Mesh of Net.....	14	2	6	18	12	29	23	15	24	27	3	7	...	...	...
<i>Calanus finmarchicus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>C. tenuicornis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>C. carinatus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>C. gracilis</i> .....	...	3	...	...	...	...	4	...	...	...	...	...	...	...	...
<i>Megacalanus princeps</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Eucaleanus elongatus</i> .....	10	2	3	3	1	3	6	3	1	1	...	...	...	...	...
<i>E. crassus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Rhinocalanus nasutus</i> .....	2	3	4	6	4	13	8	12	20	8	3	7	4	...	...
<i>Paracalanus parvus</i> .....	...	...	...	...	1	1	...	...	6	...	1	...	...	...	...
<i>Clausocalanus arcuicornis</i> (A).....	...	2	...	...	2	3	...	...	...	...	...	...	...	...	...
(B).....	...	1	...	...	...	...	3	...	7	?	11	2	1	...	...
<i>C. peregrinus</i> .....	...	...	27	...	6	5	...	2	1	7	2	...	2	...	...
<i>Ctenocalanus vanus</i> .....	...	1	6	...	1	6	...	2	2	1	...	...	2	...	...
<i>Spinocalanus abyssalis</i> .....	...	...	1	...	1	7	11	4	2	2	...	1	...	...	...
<i>S. abyssalis</i> var. <i>pygmaeus</i> .....	...	5	5	6	5	14	16	5	...	...	...	...	...	...	...
<i>S. magnus</i> .....	13	5	1	5	...	7	10	5	3	1	1	...	1	...	...
<i>S. spinosus</i> .....	8	2	5	6	1	7	11	1	3	...	...	...	...	...	...
<i>Minocalanus cultrifer</i> .....	5	...	3	...	...	4	9	...	...	...	...	...	...	...	...
<i>Monacilla typica</i> .....	4	1	...	2	...	1	3	...	...	...	...	...	...	...	...
<i>M. tenera</i> .....	...	...	...	...	2	...	...	...	...	...	...	...	...	...	...
<i>Evidens armatus</i> .....	3	...	...	...	1	...	1	1	...	...	16	9	32	1	...
<i>Aetideopsis rostrata</i> .....	...	...	...	1	...	...	...	...	...	...	...	...	1	...	...
<i>Chiridius armatus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>C. multiserratus</i> .....	...	...	...	...	...	2	2	...	...	...	1	...	...	...	...
<i>Chiridiella macrodactyla</i> .....	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...
<i>Gaidius affinis</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>G. tenuispinus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>G. minutus</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>Gaelanus major</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
<i>G. minor</i> .....	3	1	1	1	1	5	1	2	...	1	...	...	...	...	...
<i>G. pileatus</i> .....	1	...	...	...	...	1	...	2	...	...	...	...	...	...	...
<i>G. latifrons</i> .....	1	...	1	2	...	2	2	...	...	...	...	...	...	...	...
<i>Euchirella curticauda</i> .....	1	...	1	...	...	1	1	3	...	...	...	...	...	...	...

<i>Undeucheta minor</i>	1	4	1	5	..	7	6	9	1	..	..	..	..	..	..	..	..	..	..
<i>U. major</i>	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Chirundina Shrestsi</i>	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>C. parvisipina</i>	2	..	..	2	..	4	2	..	2	1	3	..	..	..	..	..	..	..	..
<i>Eucheta gracilis</i>	..	1	..	2	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..
<i>E. barbata</i>	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
<i>E. acuta</i>	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>E., sp. imm.</i>	1	1	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
<i>Scaphocalanus magnus</i>	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>S. echinatus</i>	4	..	..	1	..	1	..	7	..	..	..	..	..	..	..	..	..	..	..
<i>S. brevicornis</i>	..	..	..	1	..	2	4	..	4	..	..	..	..	..	..	..	..	..	..
<i>Scolecithricella dentata</i>	6	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..
<i>S. vittata</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scolecithrix curta</i>	..	..	..	..	..	..	..	2	1	..	1	..	..	..	..	..	..	..	..
<i>S. europecten</i>	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
<i>S. fulcifer</i>	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>S. valens</i>	..	..	..	2	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..
<i>S. emarginata</i>	..	1	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..
<i>S. ovata</i>	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>S. laminata</i>	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Scottocalanus Thori</i>	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Lopholithris frontalis</i>	1	1	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
<i>Xanthocalanus muticos</i>	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Undinella simplex</i>	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>Cephalophanes refulgens</i>	..	..	..	..	..	4	..	..	..	..	1	..	..	..	..	..	..	..	..
<i>Centropages typicus</i>	..	3	95	..	..	642	570	314	6	316	490	153	80	125	1	..	..	..	..
<i>Metricia lucens</i>	240	124	..	333	175	3	..	1	5	..	..	..	..	..	..	..	..	..	..
<i>M. princeps</i>	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
<i>M. venusta</i>	5	3	..	..	..	..	2	2	1	1	..	..	..	..	..	..	..	..	..
<i>M. brevicauda</i>	..	12	5	32	13	22	30	3	..	..	..	2	1	..	..	..	..	..	..
<i>Pleuromamma robusta</i>	40	15	19	15	5	17	24	65	..	..	1	2	..	..	..	..	..	..	..
<i>P. triphius</i>	1	2	..	2	1	1	..	1	..	..	1	..	..	..	..	..	..	..	..
<i>P. gracilis</i>	..	2	1	2	1	9	..	85	..	..	..	..	..	..	..	..	..	..	..
<i>Lucicutia flavicornis</i>	..	1	1	..	1	1	1	..	..	..	..	1	..	..	..	..	..	..	..
<i>L. magna</i>	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
<i>L. curta</i>	25	7	8	..	1	3	5	7	3	..	..	2	1	..	..	..	..	..	..
<i>L. simulans</i>	..	..	..	..	..	..	..	5	..	1	1	..	..	..	..	..	..	..	..
<i>L. grandis</i>	..	..	..	..	..	..	..	..	2	..	2	1	..	..	..	..	..	..	..
<i>Ischoeta ovalis</i>	..	..	..	3	4	3	10	2	4	..	..	..	..	..	..	..	..	..	..
<i>Duseta patumbos</i>	..	1	..	3	..	2	..	..	1	..	..	..	..	..	..	..	..	..	..

TABLE II (continued).

Vertical Hauls, between 400 and 2000 fms.	500-400 fms.				750-500 fms.				1000-750 fms.				1250-1000 fms.		1500-1250 fms.		2000-1500 fms.	
	21 m	35 h	35 i	35 f	22 b	30 k	34 e	34 f	23 a	31 d	32 k	27 b	31 c	30 i	26 b	30 i	26 b	
No. of Haul.....	36	45	45	45	36	45	45	45	36	45	45	45	45	45	36	45	36	
Mesh of Net.....	1	3	...	...	5	1	5	7	9	3	6	...	2	2	...	...	...	
<i>Heterorhabdus abyssalis</i> .....	...	1	...	...	1	...	1	1	4	1	...	...	...	...	...	...	...	
<i>H. norvegicus</i> .....	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
<i>H. spinifrons</i> .....	...	2	...	...	1	1	1	1	...	...	...	2	...	...	...	...	...	
<i>H. longicornis</i> .....	4	...	...	...	1	1	1	1	...	...	...	...	...	...	...	...	...	
<i>H. brevicornis</i> .....	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	
<i>Hemirhabdus Grimaldii</i> .....	...	...	...	...	...	...	...	...	1	1	1	...	...	...	...	...	...	
<i>Macrohabdus brevipodatus</i> .....	2	...	...	...	...	1	...	...	1	...	1	...	...	...	...	...	...	
<i>Haloptilus acutifrons</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
<i>H. longicornis</i> .....	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	
<i>H. planus</i> .....	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	...	...	
<i>Asaptilus longicaudatus</i> .....	1	...	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	
<i>Euasaptilus palambol</i> .....	2	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	
<i>E. laticeps</i> .....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
<i>Phyllopus impar</i> .....	2	2	2	...	...	...	7	2	...	6	1	...	...	4	...	...	...	
<i>Acartia Clausi</i> .....	...	...	...	...	1	...	1	1	1	...	...	...	...	...	...	...	...	
<i>Mormonilla phasma</i> .....	3	...	2	...	...	...	1	1	...	...	...	...	...	...	...	...	...	
<i>M. minor</i> .....	...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
<i>Oithona atlantica</i> .....	2	2	3	...	1	1	4	1	3	2	3	...	...	...	...	...	...	
<i>O. setigera</i> .....	...	1	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...	
<i>O. similis</i> .....	...	...	...	...	...	...	1	...	2	...	...	2	1	...	...	...	...	
<i>Idania atlantica</i> .....	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	
<i>Ponticella abyssicola</i> .....	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	
<i>Oncaea conferta</i> .....	9	21	26	...	18	8	7	18	48	16	148	20	16	20	5	...	...	
<i>O. mediterranea</i> .....	...	1	1	...	4	1	...	...	2	...	1	...	...	...	...	...	...	
<i>Conaca rapax</i> .....	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	
<i>Microsetella norvegica</i> .....	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	
<i>Bathypoda remota</i> .....	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	
<i>Agathis mucronatus</i> .....	1	...	1	...	...	...	1	1	4	...	...	...	...	...	...	...	...	
<i>Æ. dubius</i> .....	...	...	...	...	...	...	...	1	1	...	...	...	...	...	...	...	...	
<i>Æ. aculeatus</i> .....	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	
Total number of species.....	38	27	32	...	34	29	48	40	51	31	27	21	15	14	11	...	...	
Total number of specimens .....	426	191	271	...	493	188	869	804	655	446	737	251	141	221	23	...	...	

Polychæta of the 'Alert' Expedition.\* Families Hesionidæ and Nereidæ \*.  
By C. C. A. MONRO, F.L.S.

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(With 11 Text-figures.)

[Read 18th February, 1926.]

Family HESIONIDÆ, Grube.

HESIONE INTERTEXTA, Grube.

*Hesione intertexta*, Grube, 1878, p. 102, pl. 6, fig. 5.

" " Grube, Horst, 1924, p. 192.

*Occurrence* :—Port Molle, Queensland, beach and coral reef. Holothuria Bank, Torres Straits. Prince of Wales Channel, Torres Straits, 7 fms., sand. Thursday Island, 0-5 fms., sand. Flinders Claremont, N.E. Australia, 11 fms., sand and mud. Macclesfield Bank, China Sea. Rameswaram, Gulf of Manaar. Providence Reef, Mascarene Islands.

*Description* :—Eleven specimens, the largest being 49 mm.  $\times$  7 mm., and the smallest 11 mm.  $\times$  2 mm., both measurements excluding the feet. The average size of an adult specimen is about 40 mm.  $\times$  5 mm. The body-colour in spirit varies from a pale yellow to a grey, and from a grey to a pale green. The colour-pattern, except in a few examples in which traces of a brown longitudinal dorsal striping are still apparent, has disappeared. At the apex of the blade of the chaetæ the delicate covering lamella or guard is continued past the subapical tooth until it nearly meets the apical tooth. There is a single black aciculum.

*Remarks* :—The dorsal striping which Horst (1924) regards as characteristic of *H. intertexta* is found also in *H. pantherina*, Risso (= ? *H. splendida*, Sav.). Fauvel (1923, p. 324) mentions the variability of the coloration of *H. pantherina*, describing that species as being spotted with brown and with white reticulations, or striped with either elongated or rounded brown markings. Treadwell (1902, p. 184) rejects differences in colour-pattern between *H. vittigera*, Ehlers, and *H. prateata*, Ehlers, and adopts Ehlers's suggestion that such differences are probably due to sexual changes.

Furthermore, Fauvel (1911, p. 375) showed that the shape of the digitiform parapodial languet is too variable to be employed as a specific character.

\* Concluding paper of the series. See Journ. Linn. Soc. London, Zool. xxxvi. no. 240, pp. 87-77 (1924).

Chamberlin (1919, p. 189) believes that the shape of the apex of the chætal blade and especially the relation of the guard to the apical teeth give valid specific characters, and figures a series of examples of chætal blades (*loc. cit.* pl. 22. figs. 7-14). He does not, however, sufficiently distinguish between those types of chætæ in which the guard approaches the same tooth, whether it be the apical or subapical. Slight differences in the curvature of the teeth are matters of individual variation.

The relation of the guard to the apical teeth appears, however, to be constant and specific; and using this relation as a basis for classification, the species of *Hesione* fall into three and possibly four groups.

A. The guard approaches the subapical tooth.

*H. pantherina*, Risso (*vide* Fauvel).

*H. proctochona*, Schmarda.

*H. margaritæ*, Hansen.

*H. genetta*, Grube (*vide* Chamberlin).

B. The guard approaches the apical tooth.

*H. intertexta*, Grube (*vide* Chamberlin).

*H. reticulata*, Marenzeller.

*H. panamena*, Chamberlin.

*H. prætexta*, Ehlers.

C. The guard projects beyond the apical tooth.

*H. Eugeniæ*, Kinberg.

*H. Ehlersi*, Gravier, in which the chætal guard appears to be transitional between the type of Group A and that of Group B, is probably a good species.

I have found no record of the shape of the chætal blade in *H. ceylonica*, Grube, nor is this known for *H. pacifica*, McIntosh. Treadwell rightly identifies *H. vittigera*, Ehlers, with *H. proctochona*, Schmarda, but *H. prætexta*, Ehlers, which he claims is also identical with *H. proctochona*, differs from Schmarda's species in the shape of its chætal blade. Between the species within Group A and Group B severally there appear to be no valid differences beyond those of coloration. *H. pantherina* occurs in the Mediterranean; the remainder are tropical.

**HESIONE EUGENIÆ, Kinberg.**

*Hesione Eugeniæ*, Kinberg, 1857, p. 57, pl. 23. fig. 8.

**Occurrence** :—Holothuria Bank, Torres Straits.

**Description** :—One specimen, 36 mm. × 4 mm., excluding the feet. The specimen is ill preserved. All colouring has completely disappeared and both tentacular and anal cirri have been lost. Kinberg's figure (8 B) of the head, proboscis, and anterior segments is accurate, but in his drawing (8 F) of a foot he omits the dorsal languet which arises from the dorsal lip of the chæta sac.

**LEOCRATES CHINENSIS**, Kinberg.

*Leocrates chinensis*, Kinberg, 1857, p. 57, pl. 23. fig. 7.

" " Kinberg, Horst, 1924, p. 193.

" *anonymus*, Hesse, 1925, p. 15, fig. 4.

*Occurrence* :—Macclesfield Bank, China Sea.

*Remarks* :—One specimen, measuring 16 mm.  $\times$  2 mm. As Horst (*loc. cit.*) points out, this species is easily recognizable by its large conical facial tubercle.

**LEOCRATES PAPILLOSUS**, sp. n.

*Occurrence* :—Macclesfield Bank, China Sea.

*Description* :—Two specimens, measuring 12 mm.  $\times$  2 mm. and 13 mm.  $\times$  2 mm., excluding the feet. The prostomium, with the proboscis everted, is subrectangular, with two conspicuous pairs of eyes, the anterior pair being the larger. Behind the second pair of eyes are two faint pigment-spots. The facial tubercle is rounded rather than conical, and the paired tentacles are only slightly longer than the palps. The dorsal jaw-plate is single, and the proboscis is provided with a complete crown of about 24 chitinous papillæ.

The body-colour in spirit is pale yellow with no markings, and there are the usual 16 chætigers. The notopodium begins at the 4th chætiger. The dorsal chætæ are long and delicately spinous, and the neuropodial chætal blades are long and fine with small apical teeth. The lamelliform guard reaches to the subapical tooth. The cirri of the anal and pre-anal segments are missing from the examples.

*Remarks* :—This species is easily distinguishable by the complete crown of chitinous papillæ. *L. anomalus*, Chamberlin, is described as possessing a half-circle of papillæ on the dorsal surface of the proboscis.

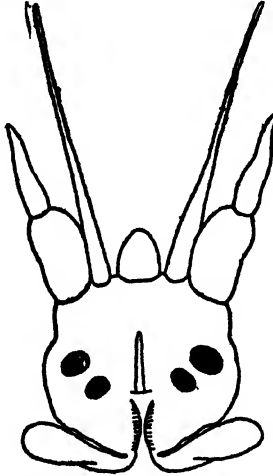
**LEOCRATES DIPLOGNATHUS**, sp. n.

*Occurrence* :—Macclesfield Bank, China Sea.

*Description* :—Four specimens, of which the largest measures 21 mm.  $\times$  3 mm. and the smallest 13 mm.  $\times$  2 mm., excluding the feet. The dorsum is a dark chestnut-brown traversed by intersegmental bands of white. The colouring is more intense in the anterior segments, and in two examples it disappears altogether behind the first half-dozen segments. The dorsum is much arched and there is the usual ventral sulcus. The prostomium with the proboscis everted is as broad as long and irregularly marked with brown anteriorly. The anterior and larger pair of eyes, which are not clearly delimited, arise on a level with the unpaired tentacle. The facial tubercle is more or less conical and not very prominent. The paired tentacles are about twice as long as the palps, which are furnished with very stout basal articles. Behind the posterior median furrow the prostomium curves back in a

remarkable wing-like pair of folds (fig. 1). The upper jaw-plate is composed of two pieces set together in the form of a bifid fan as in *L. atlanticus*, McInt. There are 16 chæstigers and the usual 8 pairs of tentacular cirri.

FIG. 1.



*Leocrates diplognathus*, sp. n.  
Dorsal view of head.  $\times 28$ .

FIG. 2.



*Leocrates diplognathus*, sp. n.  
Chætal blade  $\times 470$ .

The aciculum detaches itself from the dorsal cirrus and supports a true notopodium at the 5th foot. In addition to the two anal cirri there is a pre-



anal achæstous segment bearing long filiform cirri. The dorsal chætæ are furnished with well-marked spines, and in the neuropodial chætæ the teeth of the blade are large and widely separated (fig. 2). The lamelliform guard approaches the subapical tooth.

*Remarks* :—This species is closely related to *L. auritus*, Hesse (1925, p. 18), but is distinguished from it by the possession of double dorsal jaw-plates. Moreover, in *L. auritus* the notopodium begins with the 4th chætiger and in *L. diplognathus* with the 5th.

*IRMA LATIFRONS*, Grube.

*Irma latifrons*, Grube, 1878, p. 109, pl. 6. fig. 6, pl. 15. fig. 11.

*Occurrence* :—Port Jackson.

*Remarks* :—A single anterior fragment consisting of 26 chætigers. I do not consider that Augener (1913, p. 189) is justified in identifying this species with *Irma augustifrons*, Grube. The great breadth of the prostomium, which is more than twice as broad as long, the extreme length and slenderness of the numerous chætal blades with their claw-like apices appear to be distinctive of *I. latifrons*.

#### Family NEREIDÆ.

NEREIS (PERINEREIS) CULTRIFERA (Grube).

*Nereis (Perinereis) cultrifera*, Fauvel, 1923, p. 352.

*Occurrence* :—Singapore beach.

*Remarks* :—Five specimens, the largest measuring 67 mm.  $\times$  4 mm. and the smallest 38 mm.  $\times$  2 mm., excluding the feet.

There is an unusual arrangement in the teeth of Group I of the proboscis. There are 4 small paragnaths in a diamond-shaped pattern instead of the usual 1 to 3 in a row.

*Nereis (P.) Helleri*, Grube, *Nereis (P.) striolata*, Grube, and *Nereis (P.) perspicillata*, Grube, appear to be simple varieties of the European *Nereis (P.) cultrifera*, Grube.

NEREIS (PERINEREIS) NUNTIA, Sav.

For synonymy see Fauvel, 1919, p. 410.

NEREIS (PERINEREIS) NUNTIA, Sav., var. BREVICIRRIIS, Grube.

*Occurrence* :—Goto, Japan.

*Remarks* :—Two specimens, one complete, measuring 58 mm.  $\times$  3 mm. without the feet, and one anterior fragment.

NEREIS (PERINEREIS) NUNTIA, Sav., var. VALLATA, Grube.

*Occurrence* :—Port Jackson. Alert Harbour. W. Patagonia.

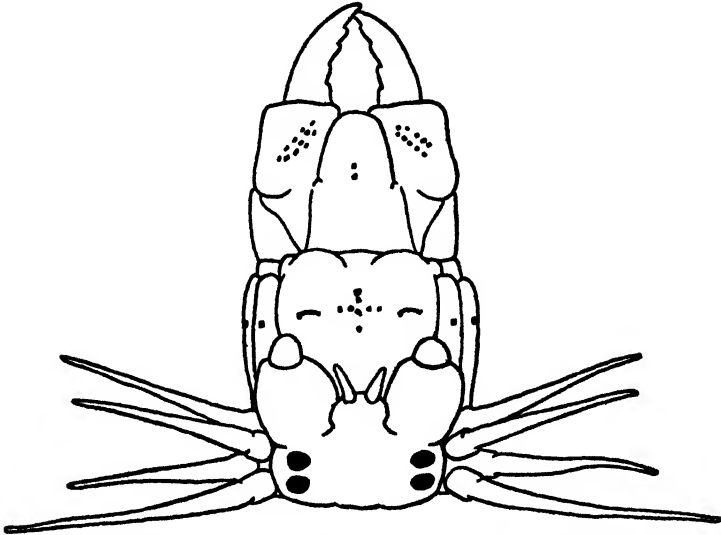
*Remarks* :—Three specimens, of which the largest measures 106 mm.  $\times$  3 mm. and the smallest 81 mm.  $\times$  2 mm. without the feet.

Fauvel (1919, pp. 410–421) has made a lucid analysis of this species and its varieties, to which I have nothing to add.

*NEREIS* (*PERINEREIS*) *BARBARA*, sp. n.

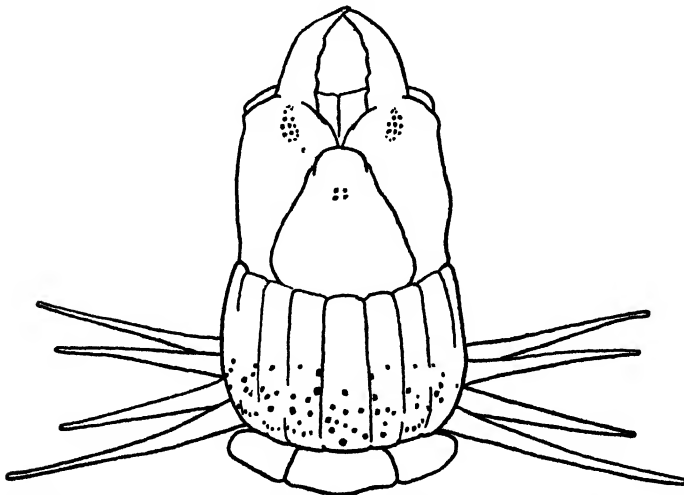
*Occurrence* :—Port Jackson, 3 specimens. "East Australia," 8 specimens. Singapore Beach, 1 specimen.

FIG. 3.



*Nereis* (*P.*) *barbara*, sp. n. Dorsal view of head and proboscis.  $\times 15$ .

FIG. 4.



*Nereis* (*P.*) *barbara*, sp. n. Ventral view of head and proboscis.  $\times 15$ .

*Description* :—The largest specimen measures 57 mm.  $\times$  3 mm. without the feet. The more common size is about 40 mm.  $\times$  2 mm. The colour in spirit is pale yellow, and all markings have disappeared except for a large dark spot on the upper surface of the superior dorsal languet in the posterior segments. The prostomium is of the usual shape and the tentacles are about

one-fourth of its length. The prominent palps end in a small knob-like terminal article. The longer tentacular cirri reach to the 3rd chætiger. The arrangement of the paragnaths is as follows:—

Group I. Two, a smaller followed by a larger.

Group II. An oblique distichous group of about twelve paragnaths.

Group III. A small transverse group of about nine paragnaths.

Group IV. A large crescentic group.

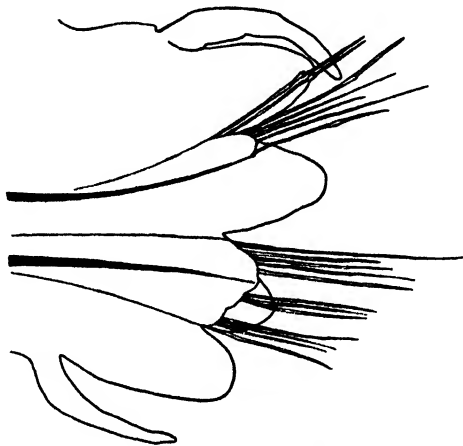
Group V. A longitudinal row of four paragnaths.

Group VI. Two small paragnaths on the border of Group V and a single large linear paragnath.

Groups VII and VIII. A band of paragnaths about four deep.

There occurs some variation in the arrangement of Group VI. Of the small paragnaths on the border of Group V there are in some examples three paragnaths, the usual two side by side and a third one above or below them. In one example there is only a single small paragnath besides the large linear one.

FIG. 5.



*Nereis (P.) barbara*, sp. n. Anterior foot.  $\times 55$ .

Regarding the feet (fig. 5), in the anterior segments there is a long dorsal cirrus projecting well beyond the superior dorsal languet. The two dorsal languets are not very prominent and the lip of the ventral chæta sac is just shorter than the inferior one. The ventral languet is subdigitiform and of about the same length as the ventral cirrus. Posteriorly the languets all become longer and more pointed. There is nothing remarkable about the chætæ and their arrangement except that there appear to be no heterogomph spinigers present.

*Remarks*:—The arrangement of the paragnaths of Groups V and VI is, as far as I know, unlike that of any other Perinereid. *Nereis amblyodonta*, Schmarda, is perhaps related in that it has a small paragnath in Group VI adjoining Group V.

**NEREIS (PERINEREIS) SULUANA, Horst.**

*Nereis (Perinereis) suluana*, Horst, 1924, p. 175, pl. 33. fig. 9.

*Occurrence* :—Darros Island in the Amirantes.

*Description* :—Eleven specimens mostly incomplete posteriorly. Size 30–40 mm.  $\times$  2 mm. The largest specimen is 44 mm.  $\times$  2.5 mm., excluding the feet.

There is a much faded brown pigment-spot at the base of both palps and of the paired tentacles. The buccal segment has also two pigment-spots on each side, one at the base of the tentacular cirri and the other obliquely placed in front of the first foot. The longest tentacular cirrus reaches only to the 3rd chætiger, and the 1st chætiger is unpigmented. That which Horst describes as “a narrow transverse black band” in my examples is seen as a dark brown band occupying about three-quarters of each segment. For the first few segments the white transverse line divides the brown band equally, but more posteriorly it gradually moves further backwards in the segment. Both dorsally and ventrally there is a faintly discernible median colour-line. In the posterior segments the dark brown bands cease, and their place is taken by two narrow transverse lines of pale brown, behind which and in the median line is a triangular patch of the same colour.

The arrangement of the paragnaths is as follows :—

Group I. Two paragnaths in a line, the smaller in front.

„ II. A roughly distichous oblique group.

„ III. A transverse group of about 3 rows.

„ IV. An oblique group of about 4 rows.

„ VI. A single ridge-shaped paragnath.

The foot has been well figured by Horst (*loc. cit.*).

*Remarks* :—The absence of all the groups except VI from the oral ring makes this species easily identifiable. There are certain differences between my specimens and those described by Horst—notably the much greater length which Horst gives for the tentacular cirri, but these are not sufficient to justify the establishment of a new species.

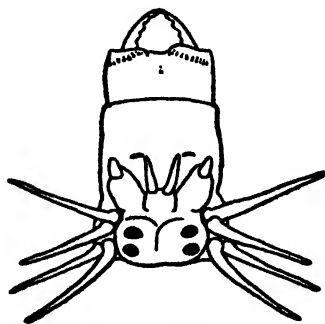
**NEREIS (PERINEREIS) CALMANI, sp. n.**

*Occurrence* :—“East Australia,” 12 specimens. Macclesfield Bank, China Sea, 2 specimens. Port Jackson, 1 specimen.

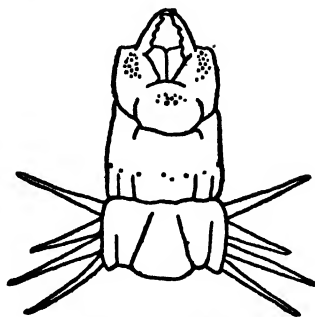
*Description* :—The largest example is 49 mm.  $\times$  3 mm., excluding the feet. The most common size is about 30 mm.  $\times$  2 mm. The majority of the specimens are in the epigamic condition. The colour in spirit is a pale yellow without any markings, and the prostomium is broader than long with very short tentacles which do not reach to the end of the basal article of the palps. They are about one-fourth the length of the prostomium. The palps are fairly slender and subulate with a short terminal article. The tentacular cirri are also short, reaching to the 3rd chætiger. The armature of the proboscis is as follows :—

- I. Two in a line, a smaller followed by a larger.
- II. An oblique subdistichous group.
- III. A small transverse group.
- IV. An oblong group of about 3 rows.
- V. Nil.
- VI. A single large transverse paragnath.
- VII and VIII. An irregular single row of 10 to 12 paragnaths (figs. 6 and 7).

FIGS. 6 &amp; 7.

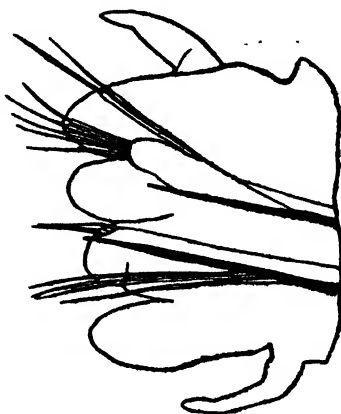


*Nereis (P.) Calmani*, sp. n.  
Dorsal view of head and proboscis.  
× 17.



*Nereis (P.) Calmani*, sp. n.  
Ventral view of head and proboscis.  
× 17.

FIG. 8.



*Nereis (P.) Calmani*, sp. n. Anterior foot. × 70.

Regarding the feet (fig. 8), there is a small thick dorsal cirrus not reaching to the end of the superior dorsal languet, which is large and conical. The inferior dorsal languet is digitiform and considerably longer than the ventral languet. The lip of the ventral chæta sac is not very prominent and the ventral cirrus is shorter than the ventral languet.

In the posterior segments the superior dorsal languet shows a considerable increase in size relative to the others.

The arrangement of the chætæ is as follows :—

Notopodium ..... Homogomph spinigers.

Neuropodium ..... *Upper bundle.* Homogomph spinigers and heterogomph falcigers.

*Lower bundle.* A single heterogomph spiniger and a group of heterogomph falcigers. The blades of the spinigers are long, slender, and slightly curved.

*Remarks* :—I have much pleasure in naming this species after Dr. W. T. Calman, F.R.S., the eminent carcinologist. As far as I know, this is the only recorded species of *Perinereis* with no paragnaths in Group V, a single one in VI, and a single row in VII and VIII.

NEREIS (PERINEREIS) AMBLYODONTA, Schmarda.

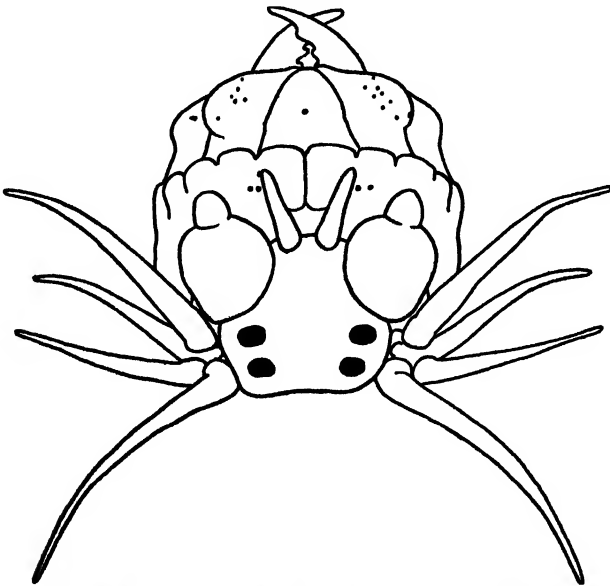
For the synonymy of this species see Augener, 1913, p. 174.

*Occurrence* :—Port Jackson.

*Remarks* :—Three ill-preserved fragmentary specimens. This species has been well figured both by Schmarda and by Kinberg.

NEREIS (LYCORIS) LARSENI, sp. n.

FIG. 9.



*Nereis larseni*, sp. n. Dorsal view of head and proboscis.  $\times 15$ .

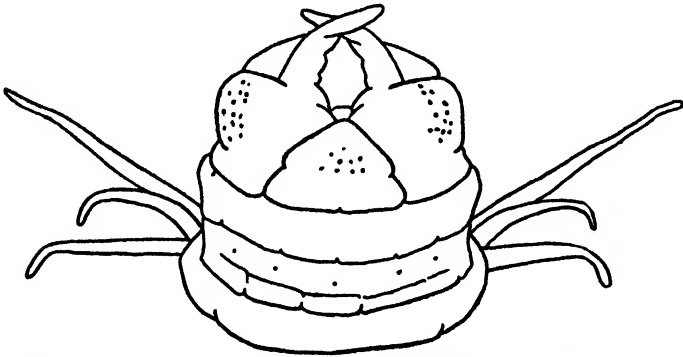
*Occurrence* :—Sandwich Islands, Antarctic Ocean, 30–50 fms.

*Description* :—Two complete specimens and one anterior fragment. The size is about 30 mm.  $\times$  2 mm., excluding the feet. The colour in spirit is a

uniform very pale red, and all traces of markings have disappeared. The prostomium is broader than long, and the two pairs of eyes are widely separated. The tentacles are less than half the length of the prostomium, and project forward for about the same distance as the palps, which are stout and have a very small terminal article. The longest tentacular cirrus reaches to the 7th chætiger. The arrangement of the paragnaths (figs. 9 and 10) is as follows :—

- I. One.
- II. A sub-distichous group of about 8.
- III. An irregular horizontal group of about 10.
- IV. A vertical group of about 15.
- V. Nil.
- VI. Two to 4 minute paragnaths in a single transverse line.
- VII and VIII. Five relatively large widely-spaced paragnaths in a horizontal row.

FIG. 10.



*Nereis Larseni*, sp. n. Ventral view of head and proboscis.  $\times 13$ .

Regarding the feet (fig. 11), there is a long dorsal cirrus, and the two dorsal languets are bluntly conical. The lip of the dorsal chæta sac is produced to form a very small dorsal languet. The ventral chæta-sac lip projects almost as far as the inferior dorsal languet. The ventral languet is of the same general form as the dorsal ones.

In the posterior segments, as is usual, the languets are more slender and pointed.

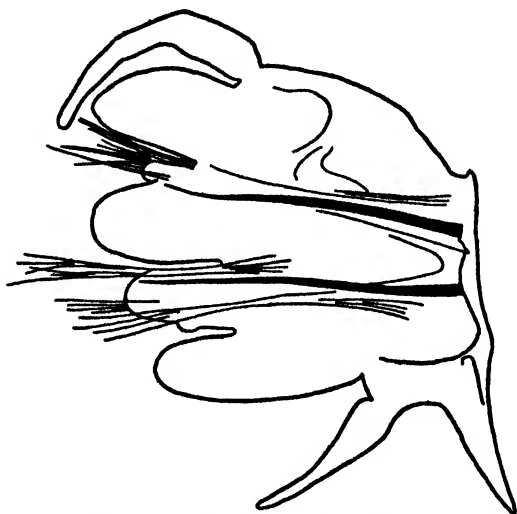
The chætæ are divided as follows :—

- Notopodium ..... Homogomph spinigers.
- Neuropodium ..... *Upper bundle.* Homogomph spinigers and a few heterogomph falcigers.
- Lower bundle.* Homogomph spinigers and a group of heterogomph falcigers.

There are no heterogomph spinigers.

*Remarks* :—*Nereis* (L.) *Larseni* belongs to that section of Lycorids in which Groups VII and VIII are occupied by a single transverse row of paragnaths. To this section belong *Nereis trifasciata*, Grube, *Nereis masalacensis*, Grube, *Nereis coutieri*, Gravier, and *Nereis unifasciata*, Willey. *Nereis Larseni* seems to be closely related to Willey's species, since in the latter no true heterogomph spinigers were found. However, the single row of minute paragnaths in Group VI, together with the absence of heterogomph spinigers, clearly separates *Nereis Larseni* from its related species. *Nereis rava*, Ehlers, is a European species which is also closely related.

FIG. 11.

*Nereis Larseni*, sp. n. Anterior foot.  $\times 70$ .

### NEREIS (PLATYNEREIS) DUMERILII (Audouin & Milne Edwards).

*Nereis* (*Platynereis*) *Dumerilii*, Fauvel, 1923, p. 359.

Two examples of this cosmopolitan species, one from the Straits of Magellan and one from South Georgia.

The *Nereis* (*P.*) *australis*, Schmarda, described by Ehlers (1904, pp. 26–28) and by Augener (1913, pp. 182–184), is a simple variety of this species.

### NEREIS ALBANYENSIS, Augener.

*Nereis albanensis*, Augener, 1913, pp. 149–153, pl. 2. fig. 6, text-fig. 14 a–c.

*Occurrence* :—Port Jackson.

*Remarks* :—One complete specimen 53 mm.  $\times$  4 mm., excluding the feet, and five fragments. All the examples are atokous. With the material at hand there is nothing to be added to Augener's full account of this species.



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On the Feeding Mechanism of a Freshwater Ostracod, *Pionocypris vidua* (O. F. Müller). By H. GRAHAM CANNON, M.A., D.Sc., F.L.S., Professor of Zoology, Sheffield University. (From the Zoological Laboratory, Imperial College of Science and Technology, South Kensington, London.)

(PLATE 11, and 5 Text-figures.)

[Read 17th December, 1925.]

THE external anatomy of the Cypridæ, the family to which the majority of fresh-water Ostracods belong, has been dealt with in considerable detail by Claus (1892). More recently Sars (1922-1925) has described them from the systematic standpoint. But in neither of these works—nor, indeed, in any other paper, as far as the author is aware—is to be found an accurate representation of the *form* of the body and limbs of any one species. The object of the present paper is to supply this deficiency, and to indicate the way in which the limbs work together.

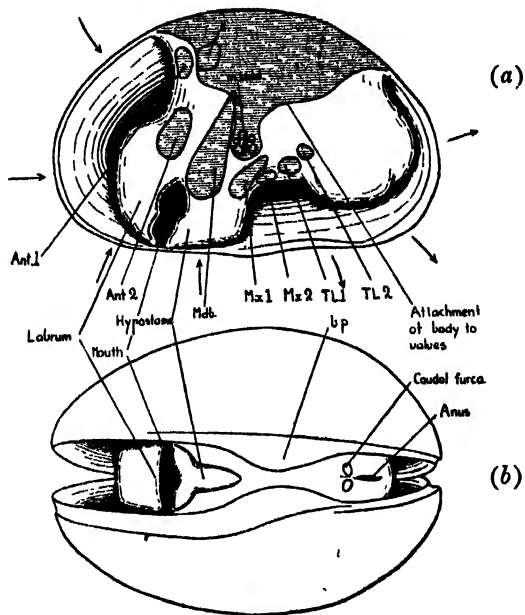
The Cypridæ, especially those occurring in fresh water, exhibit a very uniform structure. The form selected for the present paper is very common, and was chosen simply because it is typical and is very easy to rear in cultures in the laboratory. *Pionocypris vidua* (O. F. Müller) is the form usually known as *Cypridopsis vidua*. Its limbs have recently been figured by Sars (1925, pl. lxiii.).

In Pl. 11 are two representations of an adult individual. In both the body and the limbs have been drawn as if they were opaque. A key to this Plate is to be found in text-fig. 5. One drawing shows a side view after removing the left valve; the other shows a ventral view, the lower halves of the valves having been removed. The drawings were made from the study of a large number of individuals fixed in hot 70 per cent. alcohol and cleared in glycerine. The details of the limbs were studied separately from isolated limbs dissected from the body.

The form of the body is indicated in text-fig. 1. It will be seen that the large mass formed by the labrum and hypostome, which may be termed the "oral mass," is suspended from the more dorsal part of the body by a narrower "neck," so that the mouth reaches to the ventral edges of the valves. The "neck" passes through the level of the attachment of the antennæ and of the maxillules. It is particularly obvious in young forms in which the posterior genitalia have not developed.

The attachment of the body to the valves is indicated in text-fig. 1 (a). Anteriorly the attachment commences above the antennules, and runs downwards and backwards to the point where the thickened apex of the mandible pivots against the inner face of the valve. It then runs vertically downwards to the shell-attachment of the adductor muscle, and, passing ventrally round this, slopes upwards to the dorsal part of the valve almost directly above the anus. The shell-cavity is thus effectively divided into two parts by the ventrally projecting ridge formed by the adductor muscle. Into the anterior

TEXT-FIG. 1.



(a) Side view of adult *Pionocypris*, the left valve, the limbs, and the caudal furca having been removed. The attachment of the limbs to the body and of the body to the shell are indicated approximately. The arrows on the left of the figure indicate the ingoing stream and those on the right the outgoing stream of water.

(b) Ventral view of adult *Pionocypris*, the limbs and caudal furca having been removed.

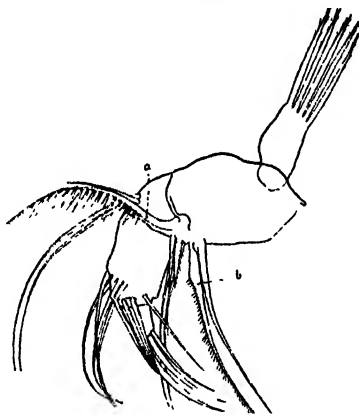
chamber project the antennæ and the mandibular palp, while into the posterior the vibratory plate of the maxillule, the posterior part of the maxilla, and the two trunk-limbs project (text-fig. 1 (a))\* . Ventrally the curved bow-shaped projections of the edges of the valves (text-fig. 1 (b), b.p.) are

\* The fact, demonstrated by the author (1925), that a typical segmental excretory organ develops in the segment of the second post-mandibular limb has been taken as conclusive evidence that this limb is a true maxilla,

so situated that when the valves are nearly closed they overlap just behind the hypostome.

*Pionocypris vidua* is, in the adult, essentially a creeping form. The younger larval stages are, on the contrary, swimmers rather than crawlers. There is considerable disagreement on this point among previous workers. Schreiber (1922, p. 493) states that *Pionocypris vidua* is a good swimmer and "von dieser Befähigung ausgiebigen Gebrauch macht," whereas Müller (1900, p. 81) states that the animal cannot even lift itself off the ground, although it makes active swimming movements. The present author cannot agree with either of these authorities. The adults can and do swim, but in a very inefficient manner when compared with a marine form such as *Cylindroleberis*. Most of the time they crawl on or in the mud, in which, incidentally, they form definite burrows. But also they crawl over the surface of

TEXT-FIG. 2.



Right mandibular palp of *Pionocypris vidua*, viewed from the median side.  $\times 445$ .

plants, feeding on any diatoms or detritus that may happen to have settled there. If disturbed, they at once make for the mud and it is then that their very inefficient mode of swimming can be observed.

The swimming-organs are the antennæ, vigorous backward and downward lashes of which propel the animal forwards. The effective part of the antenna, for this purpose, is the group of five long natatory hairs (text-fig. 5. *n.s.*) that arise from the inner face of the third compound joint, called by Claus (1894, p. 24) the "tibia." Sars (1925, p. 136) states that these hairs are densely ciliated. It would perhaps be more accurate to say that towards the ends they are frayed out. The antennules are definitely not swimming-organs. They are probably more a hindrance in this connection than otherwise. They are trailed behind over the back or moved about in an irregular manner, the hairs at their tips being spread out into a wide fan.

Skögsberg (1920, p. 69) states generally for the Cypridæ that the antennules are natatory in function, but this is certainly not the case in *P. vidua*. From the manner in which they are moved about during feeding they are probably sensory. Schreiber (1922, p. 501) states that they function in balancing and steering the body during swimming. This may be correct in other Cypridæ, but *P. vidua* does not appear to have much control over its direction when it is forced to swim. Undoubtedly, however, the wide-spread fan of the antennular hairs must serve as a parachute while the animal is tumbling through the water, and in this sense might be considered as a balancer.

In creeping the locomotion of *Pionocypris* is quadrupedal. The fore limbs are the antennæ and the hind pair the first trunk-limbs. The antennæ pull the body along, while the first trunk-limbs push it forwards. The group of spines terminating the antenna are strong, and one is very markedly "sawed" on its posterior side. They form a very effective grip in pulling the animal along, and it is undoubtedly by the aid of these spines that the ostracods can creep up the apparently clean inner surface of an aquarium glass. The long terminal spine of the first trunk-limb serves for digging backwards into the substratum. It has no "sawed" edge, but under high-power it can be seen to possess a series of oblique transverse markings that probably indicate ridges on its anterior face.

*Pionocypris vidua* is a deposit-feeder, in the sense that Hunt (1924, p. 575) defined the term. It is not selective in its feeding. It eats anything dead or alive that it happens to kick up in its wanderings.

An important factor in the feeding mechanism is the current of water that passes through the shell. This is produced mainly by two vibratory plates, a small plate on the mandibular palp (text-fig. 5, *mdb.*, *ex.*) working in the anterior chamber of the shell, taken by Hansen (1925, p. 61) to represent the exopodite, and a more important and larger plate (text-fig. 5, *mx.1.*, *ep.*), the epipodite of the maxillule (Hansen, 1925, p. 70) working in the posterior chamber. These two plates oscillate at the same speed, but when one is moving forwards the other is moving backwards. The setæ fringing the plates are not branched, but appear slightly frayed out at the ends. In sections they appear round and under high-power there can just be seen very thin sparsely distributed setules arranged along their adjacent edges. These setules all lie in the plane of the plates. The latter act in the same way as an oar used in sculling over the stern of a boat. The maxillary plate swings through an arc, the anterior part remaining practically stationary, while the posterior part moves up and down. This causes a constant stream of water to pass antero-posteriorly through the shell. The mandibular plate cannot have much importance in causing the stream when its size is compared with that of the maxillary plate. It probably functions chiefly in keeping up a circulation in the anterior chamber of the shell.

In addition to these two plates there is a minute vibratory plate on the

posterior part of the maxilla, called by Hansen (1925, p. 75) the "præpipod." A characteristic of the genus *Pionocypris* is that this plate is small. In other Cyprids it may be of considerable size, and its vibration in these forms would enhance the effect produced by the maxillary plate.

The stream passes into the shell-cavity between the antennules and the mouth (text-fig. 1 (a)). Behind this the valves are effectively closed by the hypostome and the bowed projections from the valve-edges. Posterior to the latter the stream passes out. In entering it is divided into two, one half passing on each side of the labrum. Each of these, in passing backwards, is narrowed down to pass between the adductor muscle dorsally and the edges of the shell ventrally and in so doing passes over the mandibular pulp.

TEXT-FIG. 3.

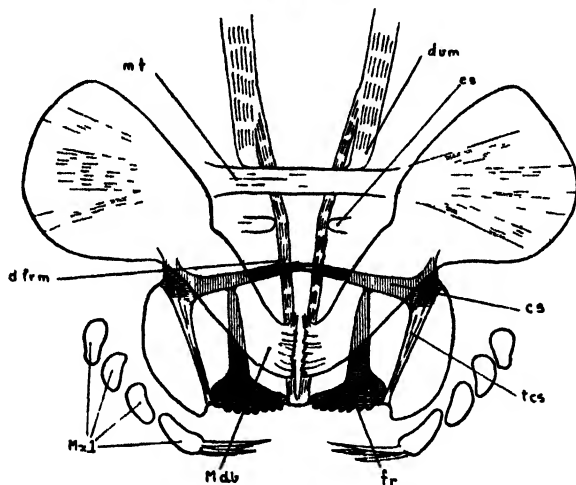


Diagram of posterior wall of oral cavity, viewed from the front, to show relation of food-rakes to mandibles and maxillules.

*c.s.*, chitinous cross-strut; *d.f.r.m.*, dorsal food-rake muscles; *d.v.m.*, dorso-ventral muscles of mandible; *e.s.*, endo-skeletal system between maxillary and maxillulary segments; *f.r.*, food-rakes; *Mdb.*, mandible; *m.t.*, transverse tendon of mandibles; *Mx1*, maxillule; *t.c.s.*, thin chitinous strand running from food-rake to cross-strut.

Most of the food eaten by *Pionocypris* is kicked up by the antennæ. The terminal spines in being pushed ventro-posteriorly into the substratum disturb a quantity of material just below the labrum. This would naturally spread in all directions, but is sucked into the shell by the entering current of water. In addition, disturbed particles are probably prevented from passing forwards by the veil formed by the natatory setæ of the antennæ. The disturbed material, once inside the shell, is now caught by the collecting hairs on the ends of the mandibular palps. The palps swing backwards and

forwards in an arc (text-fig. 5), extending from the base of the antennæ over the surface of the labrum to the mouth. As the palps move backwards the maxillules move inwards towards the mid-ventral line and slightly forwards to the level of the mouth. The palps are withdrawn forwards just before the maxillules move outwards. The food gathered on the tips of the mandibular palps is thus gripped by the terminal setæ of the maxillules while the palps are moved forwards.

An isolated palp is figured in text-fig. 2. The food-particles disturbed by the antennæ are probably seized for the most part by the group of strong claws terminating the palp, while stray particles and floating matter carried in by the more dorsal stream of water are probably filtered off by the group of four fine hairs that occur on the outer side of each palp. There are two hairs arising from the distal part of the basis of the palp that are of peculiar interest. One (text-fig. 2, *a*) runs dorso-anteriorly and curves over the surface of the labrum. It is beset with a double row of fine hairs on its lower side, and in the backwards and forwards movement of the palp must sweep back any particle adhering to the surface of the labrum towards the mouth. The other (text-fig. 2, *b*) projects downwards into the sides of the mouth. This similarly acts in pushing any particles from this region on to the mandibles.

The food entering the shell is thus first concentrated in the food-stream, then collected by the mandibular palps, passed backwards on to the maxillules and deposited at the entrance to the mouth when the latter move outwards. This appears to be the chief method of collecting food. In addition, however, the maxillæ and also the antennæ may contribute directly in gathering food-particles. The maxillæ work backwards and forwards, the fine setæ terminating the gnathobase anteriorly pushing food particles on to the maxillules. The anterior parts of the maxillæ project just in front of the bowed projections of the ventral shell edges. They thus come into very close contact with the substratum, and any particle dislodged by the edges of the shell is probably at once seized by the maxillæ and pushed forwards. The antennæ collect food simply by seizing a large mass and pressing it against the tips of the maxillules. This method of feeding can be seen if the animals are fed with milk while under observation in a shallow drop of water.

As far as this the actual collecting of the food can be observed. The further transference into the œsophagus can only be inferred. The two most important organs for the process are (1) the labral glands and (2) the armature on the anterior part of the hypostome at the back of the mouth.

The labral glands are well developed and open on the posterior face of the upper lip on a level with the biting-edges of the mandibles. It is suggested as very probable that the labral glands pour out a viscid secretion into the mouth-region, which entangles the food collected there by the maxillules.



The same process has been suggested by the author as occurring in the feeding mechanism of Daphnids (1922, p. 223) and in the nauplii of *Estheria* in which the glands are precociously developed (1924, p. 398). Storch (1924) does not agree with this. In referring to the author's description, he states that it is incomplete and partly inaccurate, but does not give any further details. Recently Franke (1925) has described the feeding of another Daphnid and has apparently neglected the role of the labral glands.

In the author's opinion Dr. Storch's detailed account of the feeding mechanism of Daphnids is itself incomplete, as it does not include the description of any food-entangling mechanism. Minute particles gathered together in a heap do not normally adhere, unless there is something to stick them together. The food-particles gathered together on the tips of the maxillules of *Pionocypris* could not remain in a compact mass, as they do when the maxillules are withdrawn, unless there were something that made them adhere. They would simply be washed away by the current of water entering the shell. That the food-particles do become entangled in some secretion is evident from stained sections. After fixation in Flemming without acetic acid and staining in Mallory's triple stain, a coagulated secretion staining blue can be seen in large quantities surrounding the food-mass and filling the whole of the mouth-entrance. It is suggested then that the food gathered together on the maxillules is clumped by a viscid secretion produced by the labral glands.

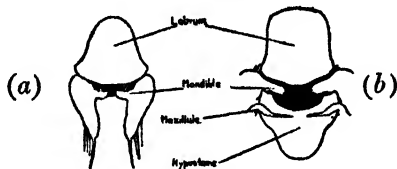
There is a possibility that the "shell-glands," recently redescribed by the author (1925, p. 4) as opening inside the valves at the base of the antennæ, are sources of a food-entangling substance. This, however, is probably not the case. When an individual *Pionocypris* is given plenty of food many stray particles of food can be seen to pass completely through the shell, and these are not entangled together in any way as they would have been if the "shell-gland" secretion were a food-entangling substance.

Schreiber (1922, p. 530) has recently described a mandibular gland in the Cypridæ, the secretion of which is passed out to the exterior by a series of fine ducts opening on to the biting-edges of the mandibles, and it might be suggested that the food-entangling secretion is produced by these glands. The figure of the gland given by Schreiber (1922, fig. T) is not very accurate, and the opening of the duct that is indicated is not at all convincing. From the author's preparations it is clear that the gland does not possess a duct leading to the exterior. The structures taken by Schreiber to be ducts are actually fine inward prolongations of the chitin. The function of the "gland-cells" is obscure, but groups of similar cells occur in the maxillules in addition to the mandibles.

The food-mass is lifted up on to the biting-edges of the mandibles by a pair of structures on the posterior wall of the oral cavity. These were originally described and figured by Zenker (1854, p. 33 and pl. 1). He

called them "rechenartige Kauorgane." A more complete account is given by Claus (1892, p. 176). These "food-rakes" are figured diagrammatically in text-fig. 3, in order to show their position relative to the biting-ends of the mandibles and to the maxillules. Each rake is in the form of an L, the serrated edge occurring on the shorter arm. The two long arms are pivoted dorsally on to the ends of a thick chitinous cross-strut figured by Claus (1892, pl. 2. fig. 6). The short arms meet together in the middle line and are held together by a thin chitinous membrane. Their outer ends are connected dorsally to the cross-strut by very thin chitinous strands that are probably elastic. Thus the upper ends are fixed at a definite distance apart, while the lower ends are more or less free to move. From the thin membrane holding the rakes together mid-ventrally a pair of small muscles run close together dorsally through the nervous system, and then through a median aperture in the endoskeletal plate lying between the maxillary and the maxillulary segments. They then diverge and attach to the sheaths of the dorso-ventral muscles of the mandibles that run from the transverse mandibular tendon to the dorsal parts of the shell.

TEXT-FIG. 4.



- (a) Reconstructed view of labrum and mandible of first-stage larva.  
 (b) Ventral view of second-stage larva.  $\times 445$ .

The food-mass collected by the maxillules is situated just below the food-rakes. Contraction of the dorsal food-rake muscles must bring the rakes together like a pair of serrated scissors. Such an action would grip the food-mass and transfer it the slight distance dorsally on to the biting-edges of the mandibles. On relaxation of the dorsal muscles the rakes would spring back, owing to the elasticity of the thin chitinous strands at their outer ends.

From the mandibles the food is passed into the œsophagus. This process cannot be observed, owing to the opacity of the shells. The mandibles certainly act irregularly, unlike the regular grinding action of the mandibles of *Daphnids*. Their biting-edges, which often overlap, end in a group of strong spines, the most dorsal of which are recurved and so point directly up the œsophagus. A detailed account of the structure of the œsophagus is given by Bergold (1910).

The only limbs that have not been mentioned in the above account of the feeding-mechanism are the second trunk-limbs. These do not take any part

in the feeding-process. The view usually put forward that they serve as cleaning organs in the posterior chamber of the shell is probably correct.

During the larval stages the chief method of feeding is the same as that of the adult from the third stage onwards. A description of the various larval stages of the Cypridae is given by G. W. Müller (1894, p. 175). More recently Schreiber (1922, p. 509) has described and figured in detail the larval stages of *Cyprinotus incongruens*. The figures, however, are very inaccurate, especially those of the younger stages. The specimens from which the figures were made are very much distorted, presumably through faulty fixation.

TEXT-FIG. 5.

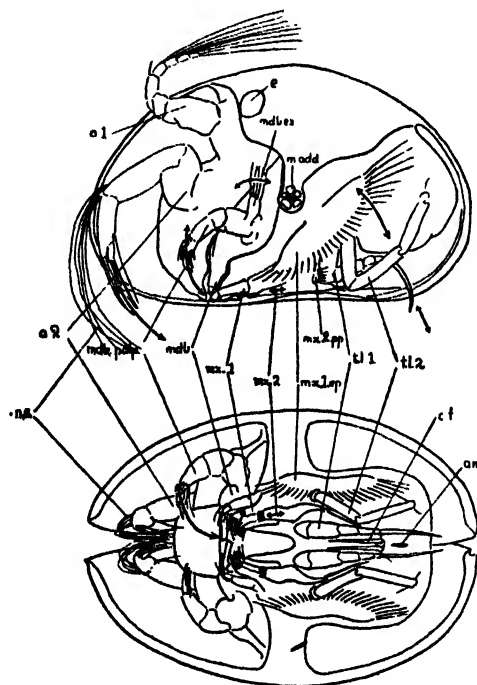


Diagram of the parts shown in Plate 11.

The double arrows indicate approximately the movement of the various limbs.

*a 1*, antennule; *a 2*, antenna; *an.*, anus; *c.f.*, caudal furca; *e.*, eye; *m.add.*, adductor muscle; *mbd.*, mandible; *mbd.ex.*, exopodite of mandible; *mbd.palp.*, mandibular palp; *m.r. 1*, maxillule; *m.r. 2*, maxilla, *m.r. 1 ep.*, maxillary exopodite; *m.r. 2 pp.*, maxillary pre-epipodite; *n.s.*, natatory setæ of antennæ; *t.l. 1*, trunk-limb 1; *t.l. 2*, trunk-limb 2.

In stage I., the so-called "naupliar" stage, the hypostome is absent, and the mandibles are a pair of minute backwardly projecting limbs (text-fig. 4 *a*). They terminate in a long spine and a group of smaller lateral spines. From frontal sections a small gnathobase can be seen arising near the base of the limb and curving forwards and upwards to the mouth, recalling the curved

gnathobase of the adult marine Ostracod *Cylindroleberis*. No feeding takes place at this stage. The anus is not yet open, and it is probable that the œsophagus also is closed, as under the highest power no distinct lumen can be seen.

Feeding commences in the second stage. The mandible has its adult form, and the hypostome, maxillules, and caudal furca have appeared (text-fig. 4 b). Each caudal ramus ends in a stout spine. The maxillule has the form of a long curved pointed limb running parallel to the hind edge of the mandible. It terminates in a large spine beset with numerous setules on the side nearest the hypostome. The maxillules presumably act as brushes, sweeping the food-particles forwards on to the mandibles.

In stage III. the maxillules have their adult form and the process of feeding is as in the adult.

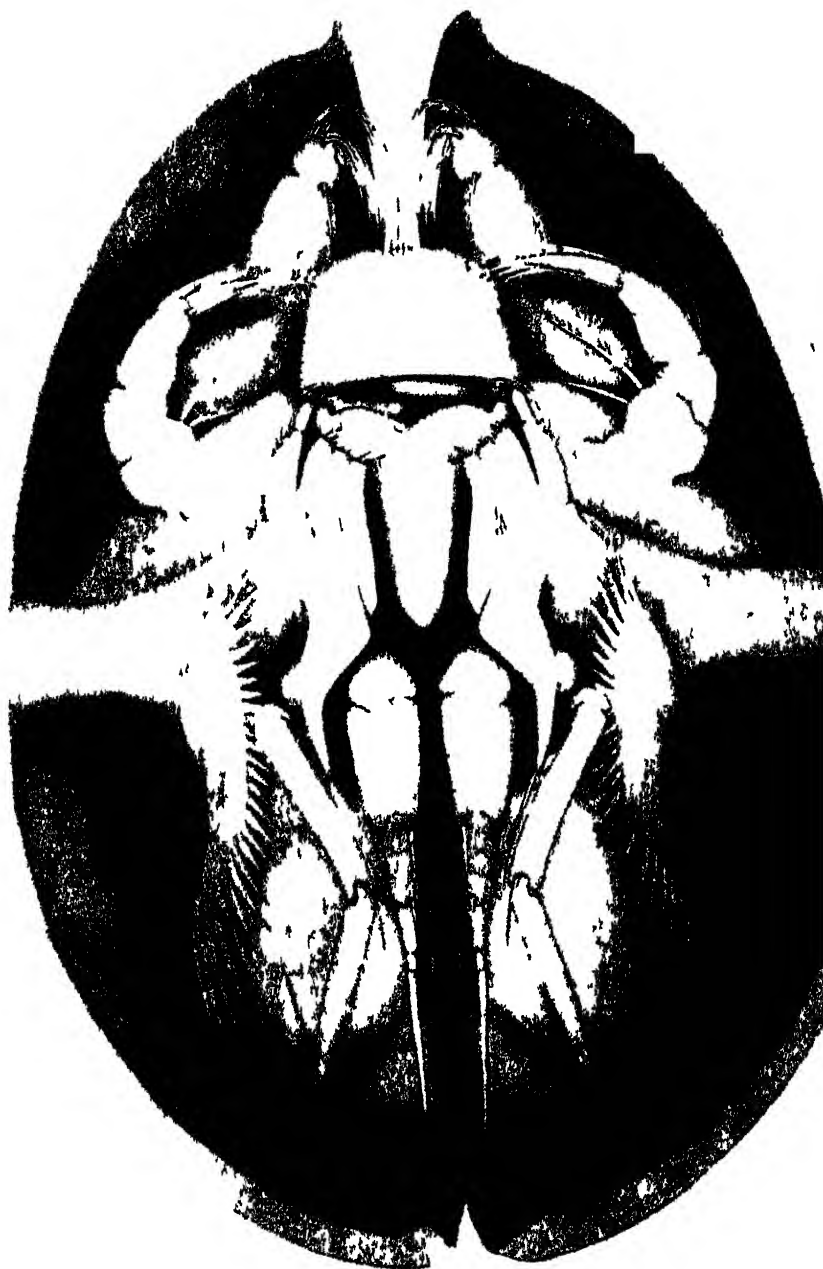
An interesting point mentioned by Claus (1894, p. 330) is that during the various larval stages there is always posteriorly a pair of organs ending in strong claws. These are simply the posterior structures used by the larva in its quadrupedal method of crawling. The first-stage larva is, however, an exception to this. The mandibles do end in strong claws, as Claus points out, but at this stage they are not used for progression. Actually the nauplius is essentially a swimming form. It is usually to be found swimming near the surface of the water. In stages II., III., and IV. the furcal rami act as hind limbs. In stage V. the maxillæ are strong pediform limbs, the gnathobasic portion being inconspicuous, and have taken over the ambulatory function from the caudal furca. In the next stage the maxillæ have developed their anterior gnathobase, but still retain posteriorly their pediform structure. The main walking-limb posteriorly is, however, the first trunk-limb as in the adult. In later stages the maxillæ assume their adult shape and the posterior walking-limb is always the first trunk limb.

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Cannon



PIONOCYPRIS VIDUA  
Ventral view.



PIONOCYPRIS VIDUA.  
Lateral view.





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## EXPLANATION OF PLATE 11.

*Pionocypris vidua*, ventral and lateral views.  $\times 220$ .

A diagrammatic key to the parts shown is given in text-fig. 5, p. 333.



*Ainigmaptilon haswelli*, n. g. et sp.: a New Alcyonarian Type. By ISOBEL DEAN, B.Sc. (Hons.), University of Aberdeen. (Communicated by Prof. E. W. MACBRIDE, F.R.S., F.L.S.)

(PLATES 12 & 13, and 1 Text-figure.)

[Read 6th May, 1926.]

*Ainigmaptilon haswelli*, n. g. et sp.

THIS interesting specimen, found at 280–300 fathoms on the Mawson Antarctic Expedition, differs so extraordinarily from any other Alcyonarian so far described that one finds it difficult to assign it to even any of the five large orders. Most unfortunately the fixation has not proved good, the specimen being entirely unsuited for any satisfactory histological study, so that the evidence on more than one important point of structure is necessarily inconclusive. Unfortunately, also, it is incomplete, with both ends missing.

That it is an Alcyonarian, in the first place, one is justified in saying from (1) the form of the autozoid, (2) the type of spicule, and (3) the internal structure of the stem.

(1) The autozooids have eight pinnate tentacles. (2) The spicules, though unique, have a distinct resemblance to those of some Primnoids, in especial to those of that extraordinary unattached form, *Callozostxon mirabilis* (see Report 'Challenger' Exped. 1889, p. 48, pls. x. & xx.), which, however, has quite different polyps, and an axis, of which there is not a trace in this specimen. (3) The internal structure of the stem is paralleled by that of many Pennatulids—most closely by *Amphiacne*.

In considering with what order it may be grouped, one may definitely rule out the Stolonifera, Alcyonacea, Pseudaxonia, and Axifera, as it bears none of their most distinguishing features. The only order to which it has any resemblance is that of the Pennatulacea (Stelechotokeæ), but even here we find points such as the grouping of the polyps, the absence of axis and the apparent absence of siphonozooids, which make its classification as a Pennatulid, to say the least, not altogether convincing.

As to its positive Pennatulid features, the following may be emphasized :—  
(a) The long narrow stem shows what apparently have been four longitudinal canals running from end to end, and this is certainly a distinctive Pennatulid feature. The wall of the stem shows that exaggeration of the mesogloæ which is commonly found in the Pennatulid stem. (b) Secondly, the arrangement of the autozooids, though unique, is not approached in any

Alcyonarian outside the Pennatulids, and is there, at any rate superficially, hinted at in some forms such as *Virgularia gustaviana* and *Virgularia halisceptrum*, which, however, have a well-developed axis. What is peculiar in our specimen is that the polyps occur in close tufts at the tips of numerous short branches that come off irregularly on the two sides of the main stem. The rounded branches bearing the autozooids may correspond to the pinnæ of Pennatulids, but, whereas in a Pennatulid the pinna is formed by the fusion of the proximal portions of several autozooids, and the walls of each zooid remain distinct so that each canal in the pinna represents the cavity of a zooid, here we find that the branch is divided into a number of canals, and that each canal is a cavity into which the coelentera of from three to seven zooids open.

On the other hand, several typical Pennatulid features are conspicuous by their absence. (1) Thus there is no trace of any axis, which is typically, though not universally, developed in Pennatulids. (2) What is also striking is the absence of a central canal at the junction of the four longitudinal septa in the interior of the stem. Vague irregular gaps (text-fig., *Ga*, p. 342) are seen in the central tissue in the one portion of the stem at one end where the septa have remained untorn, but there is no trace of a definite axial canal. An entire absence of a definite axial canal is reported, it is true, in the genus *Echinoptilum*, which has no axis, but in other forms where the axis is absent, such as *Cavernularia elegans* and *C. obesa*, a small central canal is present. (3) While the autozooids are comparatively large and with well-preserved structure, there is no convincing proof of the presence of siphonozooids. The only hints of them are small whitish specks, often slightly prominent, which occur in irregular rows on the more exposed side of the main stem. But these are admittedly unsatisfactory, since the sections unfortunately show no trace of any internal structure. They are most probably cavities containing bunches of spicules.

In spite of these difficulties it seems reasonable to give *Ainigmaptilon* a doubtful place among the Pennatulacea till further specimens are forthcoming.

The habit of growth presents another problem. Unless one entertains the rather remote possibility that the specimen had originally a fine supporting axis which was torn out or left behind in the process of dredging, the extreme weakness and flexibility of the narrow stem must have made it quite impossible for the colony to grow erect. It is possible that what we have of the specimen is merely a terminal tassel-like rachis which was supported by a strong and much elongated peduncle.

The specimen (Pl. 12. fig. 3) has a striking appearance, suggestive of an elongated, delicate, flexible inflorescence. It is approximately 18 cm. long, and consists of a narrow, very flexible stem, with an average diameter of

2 mm., from which on either side, but on the whole more towards the ventral (metarachidial?) surface, short stout branches arise irregularly at average distances of 2.5 mm. These grow out at right angles to the stem, either horizontally or sloping ventrally. In view of the probable Pennatulid nature of the colony, the barer, more exposed portion of the main stem will be termed here dorsal—that is, prorachidial.

On this dorsal side of the stem are seen irregular rows of small white and yellowish specks, some of which are slightly prominent. These may possibly be regarded as rudimentary siphonozooids, but we do not consider this at all probable. Scattered over the ventral and lateral surfaces there are a few similar specks.

The mode of branching is peculiar. Each short stout branch leads on, in a manner to be presently described, to a dense cluster of small autozooids, and since many of the polyp-clusters of opposite and adjacent branches meet, little of the stem can be seen from the ventral surface. The branches increase slightly in size towards one end of the colony, but we cannot say which end. The base of the main trunk of a branch (Pl. 13. fig. 6, *a*) is 2 to 3.2 mm. in diameter, and the total length from base of trunk to top of polyp-cluster is 4 to 8 mm. The main trunk of a branch, rounded and tapering slightly from the base, divides into two to three (more typically two) secondary twigs (Pl. 13. fig. 6, *b*), but after this the branching is extremely irregular. Each secondary twig gives rise to small tertiary twigs (Pl. 13. fig. 6, *c*) varying in number from three to eight or nine. Some of these are terminal, bearing four to seven or even more polyps. Others divide into two or three further very minute twigs. These also may be terminal, bearing four to seven polyps, or may divide still further into twigs so minute that it is difficult to distinguish them, except microscopically. Each of these bears three to five minute polyps. This very irregular mode of branching is utterly different from anything seen in the superficially somewhat similar tufts of *Virgularia gustaviana* or *V. haliscepum*.

A zooid arises from a terminal twig by a narrow neck (Pl. 12. fig. 2, *Nk*) (or polyp-stalk) which bears the cup-shaped body of the polyp, the mouth and tentacles of which are protected by the long projecting points of five to eight (probably eight) spicules (Pl. 12. fig. 2, *Pt*). On both neck and polyp-body can be seen eight dark bands, doubtless corresponding to the mesenteries. The average length of a zooid, including neck, is 1 mm. The average breadth of the polyp-body is 0.3 mm. The average breadth of neck is 0.06 mm. The tentacles, which attain a length of 0.3 mm., are in most cases concealed by the rather incurving spicule-points, but they are seen to bear on each side a single row of eight to nine short pinnules.

A minute group of what appear to be rudimentary autozooids was found laterally on one portion of the main stem. At this point an irregular cavity

in the stem-wall, which is here more than usually thick, connects by a narrow opening with one of the four longitudinal canals and opens exteriorly into the cavity of a tentacle-like outgrowth in which two septa run obliquely. This outgrowth bears three polyps (Pl. 13. fig. 4, *Rud-Zo*), each connected with it by a comparatively long neck (Pl. 13. fig. 4, *Nk*). The cœlentera of these open into the cavity of the tentacle-like stalk. In these cup-shaped bodies small rudimentary tentacles are found as lobes round the margin of the mouth; and there can also be seen a gullet and faint traces of mesenteries. The average size of these zooids is 0.26 mm. by 0.15 mm., thus very much smaller than the typical forms. The length from the junction with the main stem to the tip of the stalk is 0.8 mm. Growing beside this compound outgrowth, and with a cavity connected with the central canal by the same passage, is a solitary minute stalk, bearing a very rudimentary polyp. The length of this stalk and polyp together is 0.2 mm. There is thus a hint of dimorphism among autozooids, for the appearance presented is not in the least like the origin of a new branch.

Any idea that these dwarf zooids are siphonozooids reduced to vestigial numerical representation may be ruled out. In the first place, their origin here is compound and not simple as is that of a siphonozooid. In the second place, we must recognize the presence of small tentacles, which are absent in siphonozooids, except in some of the Umbellulidæ and Chunellidæ, which have one tentacle.

*Spicules* (Pl. 12. fig. 1).—(A). In the wall of the main stem there are oval or irregularly oval scale-like spicules, with (B) one end occasionally prolonged into a short arm. These spicules bear a few minute warts and a central or excentric nucleus, from which radiate several fine striations. The dimensions are 0.1 mm. by 0.05 mm. to 0.3 mm. by 0.15 mm. A few spicules of this type occur in the walls of the branches.

II.—In the polyp-walls there are (C) very small irregularly shaped scale-like spicules, some with minute warts and with finely-toothed edges. The types varied in greatest length from 0.03 mm. to 0.1 mm. There are also (D) flat spicules which are roughly isosceles triangles in shape, with a centro-basal nucleus (sometimes wanting) from which radiate first minute warts and then numerous fine ridges which project slightly beyond the outer margin, thus resulting in markedly toothed edges and a very striking general feathery appearance. The basal edge is the only one that is untoothed. (E). In many spicules of this type the apex is prolonged into a narrow process, which is less than half the width of the basal portion, straight or slightly bent, covered with longitudinal or slightly oblique ridges which again give a rough outline, but with no warts. The length of these slender processes varies from a little more than half the entire length of the spicule to an almost negligible size. (F). In some forms the basal portion is considerably

reduced in breadth (*e.g.*, 0·08 mm.) and without ridges. The following measurements were taken:—Total length 0·25 mm. to 0·52 mm.; breadth of lower portion 0·12 mm. to 0·15 mm.; breadth of apical process 0·03 mm. to 0·06 mm. There are also (G) numerous squarish plate-like spicules with minute warts. One edge is smooth, and often bears a middle marginal nucleus with fine striations radiating from it. On the opposite edge and occasionally on the lateral edges there are comb-like teeth. A side of this approximately square spicule varies from 0·1 mm. to 0·5 mm. Some are slightly more irregular in form. (H). Some much less numerous spicules were seen which can be described exactly by apposing the smooth edge of the squarish spicule (type (G)) to the smooth basal margin of the triangular feathery spicule (types (D) or (E)). In some of the spicules a faint crack can be seen at this line of junction, running from what is now a central nucleus either right across the spicule or only a part of the way. In others there is no trace of any crack. It is thus obvious that many of the spicules of types (D), (E), and (G) are really the halves, broken apart, of this last spicule (type (H)). This is confirmed by the fact that there is always one central nucleus in type (H), whereas in types (D), (E), and (G) the marginal nucleus may or may not be present, this depending, one supposes, on whether the break took place above, below, or through the middle of the central nucleus. It is also easily seen that they would readily break, as a large portion of the upper half projects from the polyp-body and might easily snap off during the process of boiling out the spicules. One cannot be sure, however, whether they are *all* broken halves or whether some of types (D), (E), and (G), especially the more irregular spicules of (G), may not be really separate spicules. There are also (J) circular scale-like spicules with toothed edges and a central nucleus. In some warts radiate outwards from the nucleus, and in many there are a few marginal ridges extending inwards for a short distance. The diameter of these circular spicules varies from 0·14 mm. to 0·18 mm.

Excluding type (C), the micro-spicules, one can trace in these spicules two lines of evolution. I. A series of the smooth spicules can be suggested, the simple oval of type (A) leading on to the isosceles triangle shape of type (B). II. A series of the feathery spicules would start from the rounded spicule type (J), with a toothed edge and a few marginal ridges; this would lead to the isosceles triangle shape and the extreme featheriness of types (D) and (H). The end of the series would be reached in types (E) and (F), where the apex of the triangle is drawn out into a long and narrow process. We cannot leave these spicules without again emphasizing their convergent resemblance to those of Primnoidæ.

All the spicules are colourless.

Colour of the specimen in spirit: the polyps and branches grey-white to grey-yellow; the stem brownish with grey-yellow and whitish specks.

*Internal Structure.*

*Branch.*—At the junction of branch and main stem is a relatively stout wall (0·05 to 0·15 mm. in thickness), similar to the outer wall of the main stem, and penetrated by a few (2 to 4) narrow passages. The base of the branch is formed of mesogloea, riddled with numerous anastomosing solenia.

From this mesogloéal mass narrow septa arise (Pl. 13. figs. 7, 8, 10, 11, *Sept.*). These vary in number according to the number of ultimate twigs, for, on tracing these septa through serial sections, one finds that each septum terminates at the point of junction of two twigs (Pl. 13. fig. 7. 1, 2, 3, 4). As has been stated before, every ultimate twig bears from three to seven zooids, so that each canal between two septa is a cavity into which the coelentera of three to seven zooids open.

Down the centre of each septum runs a narrow intra-septal cavity (Pl. 13. figs. 7, 8, 11, *Int-Sept*), to which we are unable to attach any significance. There is no trace of a definite epithelial lining.



Transverse section of the main stem.

The canals of ultimate and penultimate twigs are filled with ova, each ovum surrounded by its follicle. Most lie free, but one or two are apparently attached by strands of tissue arising from the wall of the twig. If this is the case they must have been produced in the twig, probably from a delicate continuation of the mesentery. As already explained, it is not possible to determine this, owing to the imperfect preservation of the specimen.

*Main Stem.*—The mesogloea of the outer wall of the main stem is considerably thickened; fine fibrils and many small cavities or canals can be distinguished in it which give it a spongy appearance (text-fig., *Mes*). No trace of the cellular structure of the ectoderm or the endoderm is preserved. The outer portion of the wall is often very spongy in texture, and in portions of the stem the whole wall is riddled with small cavities.

A considerable number of larger cavities, generally oval in shape and often containing spicules, are distributed irregularly in the stem-wall (text-fig., *Sp*). Many of these open to the exterior by a narrow neck or more



directly, and occasionally the cavity lies in a slight projection of the outer wall. It is just possible that some of these cavities are siphonozooids, but undoubtedly others are merely spicule-filled gaps in the mesogloea.

Along the internal cavity of the stem run four longitudinal septa (text-fig., *Long-sept* ; Pl. 13. fig. 4, *Long-sept*), the bases of which are attached continuously to the wall. Each is considerably thickened from the base inwards for nearly half its length, but then tapers to a narrow strip. In the thicker half the septal mesogloea is riddled with numerous small cavities ; the narrower half contains a smaller number of larger cavities arranged in a string. Except for one small portion of stem from one end of the specimen, these septa lie loose in the central cavity, the free end of each showing a torn edge. In this one portion they all join to form an irregular central mass ; but though this mass contains ill-defined cavities (text-fig., *Ga*) there is no sign of a definite axial canal nor, as we have said, any trace of an axis.

The generic name of this remarkable new type is chosen in reference to the present puzzle of its systematic position (*ἀίνιγμα*, a riddle ; *πτίλον*, a feather or wing). The specific name expresses our indebtedness to the late Professor W. A. Haswell, F.R.S., F.L.S., of Sydney.

#### SUMMARY.

Description of *Ainigmaptilon haswelli*, n. g. et sp., obtained on the 21st December, 1913, from a depth of 283–300 fathoms at Station 2 on the Mawson Antarctic Expedition. It is a unique type of Alcyonarian, probably referable to the order of Pennatulids. From a narrow main stem, without an axis numerous short side-branches are given off which subdivide irregularly into twigs bearing many small autozooids. There is no satisfactory evidence of the presence of siphonozooids; small white specks on the main stem appear to be merely groups of small spicules projecting on the surface. On one portion of the stem is a group of small rudimentary autozooids. The spicules of the colony are strikingly like the Primnoid type (*Axifera*). The systematic position is doubtful. The most striking Pennatulid feature of the colony is the presence of four longitudinal septa in the main stem. In addition, the side-branches are most nearly comparable to, though not identical in structure with, the pinnæ of the Pennatulids *Virgularia gustaviana* and *V. halisceptum*. Pennatulid features that are missing are (1) siphonozooids ; (2) a definite axial canal ; (3) an axis. It is possible, however, that the axis was separated from the colony in the dredging, and, although this is rather a remote possibility, it is borne out by the torn condition of the septa. The holotype will be returned to the University Museum, Sydney.

## ABBREVIATIONS.

<i>Autoz</i> . . .	Autozoid.	<i>Sec-Tw</i> . . .	Secondary twig.
<i>Ga</i> . . . . .	Vague gap in central mass.	<i>Sept</i> . . . . .	Septum.
<i>Inter-can</i>	Inter-septal canal.	<i>Sol</i> . . . . .	Solenia.
<i>Int-sept</i> . .	Intra-septal cavity.	<i>Sp</i> . . . . .	Spicules in cavity.
<i>Long-can</i>	Longitudinal canal.	<i>St</i> ] . . . . .	Stalk, from which the rudimentary zooids arise.
<i>Long-sept</i>	Longitudinal septum.	<i>Tent</i> . . . . .	Tentacle.
<i>Mes</i> . . . .	Mesogloea.	<i>Ter-Tw</i> . . .	Tertiary twig.
<i>Nk</i> . . . . .	Neck.	1, 2, 3, 4 . .	Termination of septa between twig bases.
<i>Pass</i> . . . .	One of the narrow passages connecting the solenia at base of branch with a longitudinal canal of the main stem.	<i>a</i> . . . . .	Main trunk of side-branch.
		<i>b</i> . . . . .	Secondary twig.
		<i>c</i> . . . . .	Tertiary twig.
<i>Rud-Zo</i> . .	Rudimentary zooid.		

## EXPLANATION OF THE PLATES.

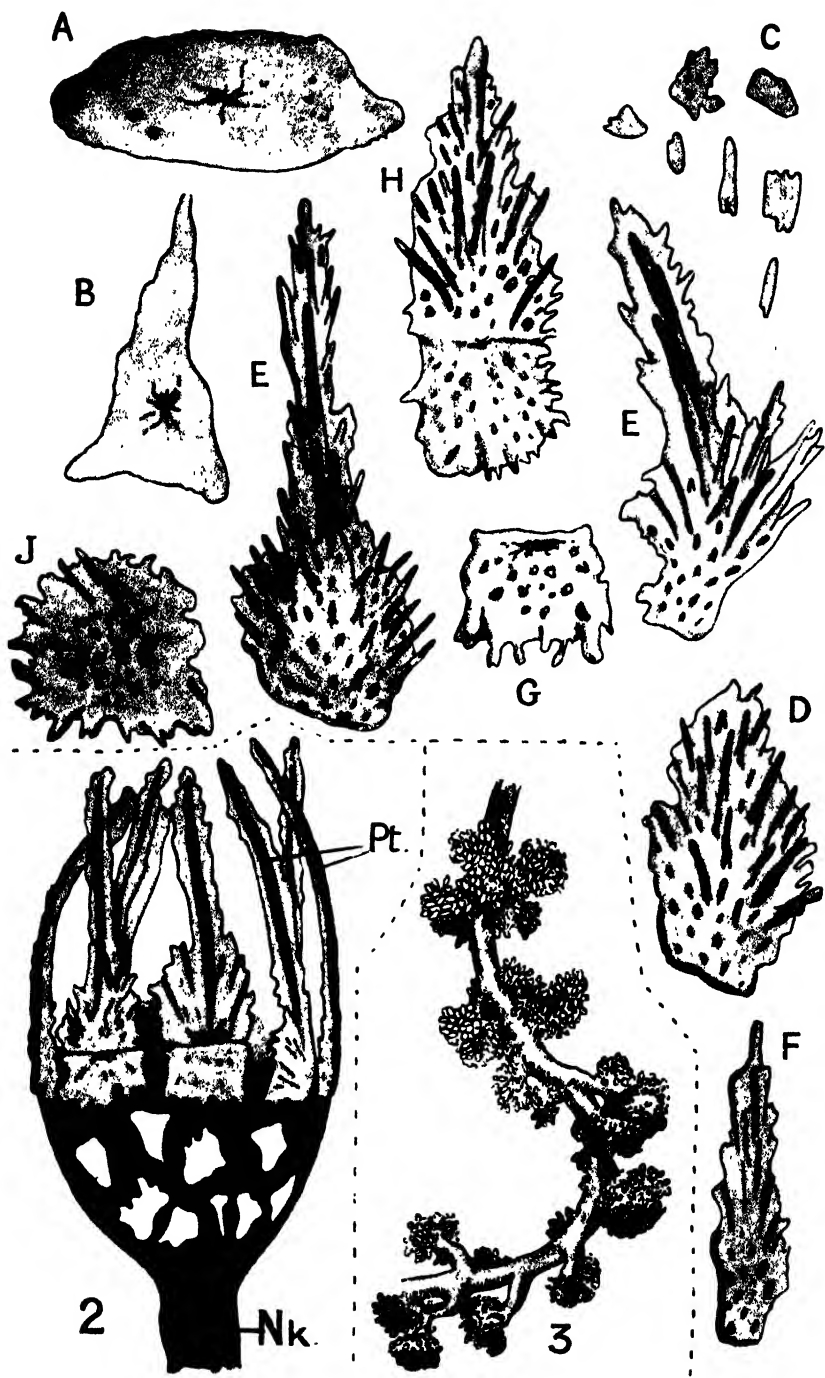
## PLATE 12.

- Fig. 1. Spicules.  
 2. Arrangement of spicules in autozoid. Semi-diagrammatic. The tentacles are not figured.  
 3. "Dorsal" view of specimen.  $\times 1.25$ .

## PLATE 13.

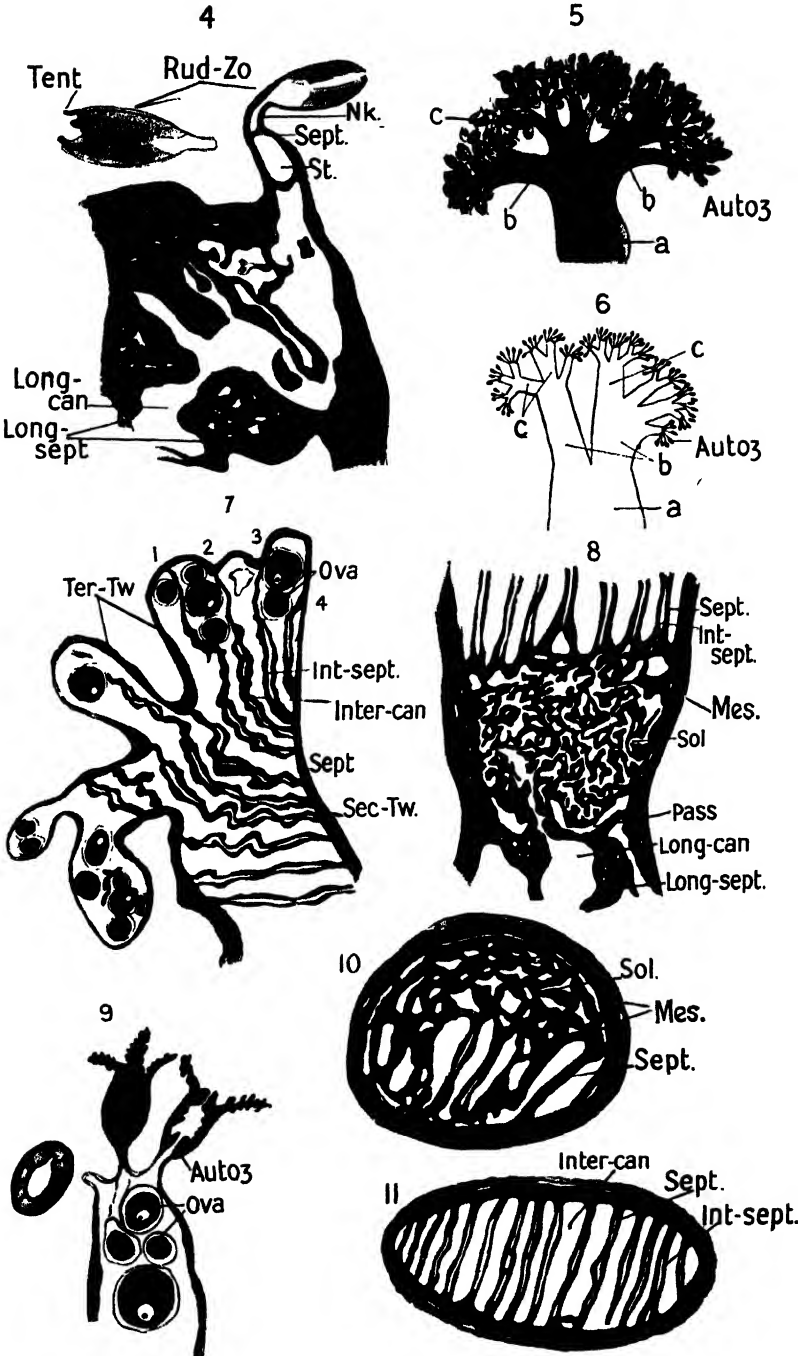
- Fig. 4. Transverse section of portion of main stem, with rudimentary zooids.  
 5. Side-branch, enlarged.  
 6. Diagrammatic representation, as if in one plane, of the mode of branching of a side-branch.  
 7. Longitudinal section of a portion of a side-branch showing the septa terminating at the junction of the twigs.  
 8. Longitudinal section of the base of the side-branch, with a portion of the main stem from which it arises. The mesogloéal mass, perforated with solenia, is seen with the septa of the branch arising from it.  
 9. Longitudinal section of an ultimate twig with autozooids opening into it.  
 10. Transverse section of base of side-branch showing mesogloéal mass and bases of some of the septa.  
 11. Transverse section of the "trunk" of a side-branch.

I.



AINIGMAPTILON HASWELLI.





AINIGMAPTILON HASWELLI.



(PLATES 14-16.)

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(i.) **Historical Notes.**

THOUGH earlier writers, notably Sternberg (1825)\*, Burmeister (1843), and Salter (1849) had described or figured early stages of particular species of Trilobites, the first of the more complete studies on Trilobite development were admirably and carefully recorded by Barrande (1852).

Examination of the existing Bohemian Trilobite collections and of the results of twelve years' fossil-collecting by parties of his own organising, enabled Barrande to establish detailed evidence of metamorphosis in *Sao hirsuta* Barrande, in *Dalmanitina socialis* (Barrande), and also less complete evidence in twenty-four other Bohemian species of Trilobites.

\* In the text only the date of publication is given; full references are cited under the heading V. Literature.

The results of this work and work on similar lines by Salter (1866), Walcott (1877, 1879, 1886), Ford (1877), Matthew (1877 & 1889), and Beecher (1893 & 1894) were added to and summarized by the last-named in an epoch-making paper in 1895.

Beecher co-ordinated previous studies and deduced \* that "all the facts in the ontogeny of trilobites point to one type of larval structure," which type he termed the protaspis, a larva which he described as \* "homologous with the nauplius or meta-nauplius of the higher Crustacea." The closeness of these "homologies" was, however, questioned later by other writers, notably Kingsley (1897).

Beecher's work stimulated research, though until 1914 but few ontogenies were added to Beecher's list.

A recent paper by Warburg (1925) summarizes critically most of the published developmental histories, and discusses their bearing upon a classification of trilobites.

It is perhaps regrettable that, apart from work by Raw (1907 & 1925), little evidence has been added from British deposits to the work in which the names of Barrande and Beecher have long been famous.

The Shineton Shales of Shineton Brook (Shropshire) have been known from the time of Salter and Aveline (1854) to contain plentiful trilobite remains and have provided material from which Raw (1925) has claimed, in a study of the development of *Leptoplastus salteri* (Call.), to have reached important conclusions concerning Trilobite affinities. Raw in 1907 also gave a description of the adult and a few notes on the development of *Shumardia pusilla* (= *Conophrys salopiensis* Callaway) in the Monograph of British Cambrian Trilobites.

Intermittent collecting work has during the past three years furnished the present writer with more plentiful specimens of this fossil, and the new material forms the basis of this paper.

#### (b) *Shumardia pusilla* (Sars).

Though Callaway in 1874 and 1877 described this Shineton Shale fossil as *Conophrys salopiensis*, Linnarsson pointed out later (1878) that it closely resembled a form which Sars had described from Norway in 1835 as *Battus pusillus*, and that both this form and Callaway's fossil probably belonged to the genus *Shumardia* of Billings.

Moberg in 1890 described and figured a pygidium which he referred to *Shumardia pusilla* (Sars) since he had found it associated with a cephalon resembling that of *S. pusilla* in the Ceratopygeskiffer at Ottenby (Sweden), that is, in beds of similar geological age to those from which the cephalon had originally been described by Sars.

\* 1895, *loc. cit.* p. 169.



In 1906, however, Moberg and Segerberg wrote (in Swedish):—

“that since a pygidium is not known from Norway, the species (*S. pusilla*) can hardly be considered fully fixed . . . until the constitution of Sars's species is actually verified, we remain dubious, although we still retain the *S. pusilla* identification of Ottenby, since, for the present, it seems likely.”

Raw and Lake (1907) described the Shineton specimens of *Shumardia* as *S. pusilla* (Sars) though, judging from Moberg's 1890 figure and description, there are minor differences between the Ottenby and Shineton pygidia, for the Ottenby specimens show a narrower axis, an absence of appreciable fulcræ in the pleuræ, and a slightly different outline.

A careful drawing has been kindly sent to the present writer by Dr. Løif Störmer, of Oslo, showing two pygidia of *S. pusilla* (Sars) which he has recently collected from the Ceratopyge-Shales of Vakkerø (Norway), and these might be considered as fixing the pygidium of the species defined by Sars. These pygidia conform in breadth of axis, in position of fulcræ of the pleuræ, and in outline more closely with Shineton specimens of similar size than does the Ottenby specimen, but, unlike the Shineton and Ottenby specimens, the Norwegian specimens have no tuberculated border; this, however, may conceivably be a question of preservation.

It seems, therefore, that the question of complete identity of Shineton specimens with the topotypes of Sars's *B. pusillus* is not yet definitely settled, but the policy of Raw and Lake is followed, and the Shineton specimens are here recognized as members of the species *Shumardia pusilla*.

In the Shineton Shale development in the Wrekin district of Shropshire, *Shumardia pusilla* is present as the index fossil of a high zone in the Tremadocian Series, and the species appear to be confined to this zone. In Scandinavia it shows a wider range, having been recognized at levels below (L. Störmer, 1920) and above (Moberg and Segerberg, 1906) the true *S. pusilla* zone.

In Britain the species has been recorded from the zone bearing its name in the Tremadocian of the Arenig District by Fearnside (1905), and by the same writer in 1910, from a similar level in the Tremadoc Country, though Lake (1907) has described varietal distinction in all the Tremadoc and in some of the Arenig area specimens.

A further record of the species is due to Raymond (see reference under Bassler), for *S. pusilla* is quoted from the *Diplograptus dentatus* zone of the Levis Division of the Canadian Series at Point Levis, Quebec.

Matthew in 1902 queried the validity of the genus “*Conophrys* (*Shumardia*),” stating, on questionable evidence, that

“*Conophrys salopiensis* therefore may very well stand as a developmental stage of *Asaphellus homfrayi*, somewhat more advanced than the youngest form ascribed to this species from the Canadian Beds.”

In our collection, young specimens of *Asaphellus homfrayi* exist which are considerably smaller and very different in aspect from the adult and from the

later larval stages of *Shumardia pusilla* (i.e., *Conophrys salopiensis*), and considerable evidence can be adduced that Matthew was in error.

This subject, however, will, it is hoped, be treated more fully in a later paper.

(ii.) *Technique.*

*Shumardia pusilla* can be collected from the *S. pusilla* zone outcrop of the shales in Shineton Brook, for it occurs more or less throughout that development, being particularly abundant at both high and low zonal levels. The specimens from the lower levels show no characters differing from those in the higher levels, but since more material is available from the high levels, this material alone is described in this paper.

The fossil, like most of the Shineton Shales trilobites, is preserved in a soft grey shale as internal casts and external moulds, the integuments having been dissolved away.

Where possible both cast and mould of each individual specimen have been collected, and it is found that the internal cast shows the general characters better since its margins more frequently lend themselves to cleaning with a needle and a true outline can be obtained. The external mould is, however, in most specimens a better guide to the determination of the external ornament.

The trilobites are sometimes found lying at an angle to the bedding-plane and frequently they show partial enrolment, so that, to minimise projection errors, the shale fragments bearing the specimens were always placed on a plasticine base, and that part of the trilobite to be measured was arranged to lie in a plane normal to the microscope-axis.

The measurements were recorded in every case only from the internal casts and were obtained by means of a microscope fitted with a rotating stage and with an eye-piece micrometer, the smallest graduation of which, with the magnification used, represented 0.0093 mm.

Measurements obtained in this manner were collected into graph form and various curves were plotted. This method has been found of immense value in grading the specimens and growth-rate changes become relatively easy to appreciate.

It was noticed that the curves formed from measurements of specimens in the higher zonal levels were in no way modified when measurements from the lower-level specimens were added.

The figured reconstructions (Pl. 14) were each made as far as possible from the measurements and characters of one specimen, but it was found necessary in almost every case to consult other specimens of the same Degree to fill in such points of detail as were absent from the particular specimen chosen as a type.

Where length measurements have been quoted in the text, these measurements have always been taken along the median axis of the dorsal shield.

## (iii.) Terminology.

## (a) General.

The usually accepted terms applied to the structural units of trilobites have been adopted throughout this paper with the possible exception of the terms *glabella* and *pygidium*.

The term *glabella* is applied in the sense used by Salter—*i. e.*, to include the occipital segment; this usage avoids confusion in cases where the occipital furrow is not developed.

The term *transitory pygidium*, a translation of the expression “*pygidium transitoire*” (Barrande, 1852, pp. 264 and 400), has been adopted to emphasize the different constitution of the larval and adult posterior shields, for, as Barrande stated (*loc. cit.* p. 400):—

“Le pygidium proprement dit, c.-à-d., la partie de l'enveloppe formée de segmens soudés ensembles d'une manière permanente, n'existe pas durant toute la première période du développement, et il n'apparaît qu'à fin de cette époque. Jusque là, nous ne trouvons qu'un pygidium que nous nommerons *transitoire*, c.-à-d., composé d'un certain nombre de segmens, dont la présence est indiquée sur l'axe et sur les lobes latéraux, mais qui ne sont qu'en voie de formation pour devenir des segmens libres ou thoraciques.”

## (b) Nomenclature of the Stages in Trilobite Development.

Barrande (1852) provided a temporary classification of trilobite developmental histories based upon the characters of the earliest known stages of the species at his disposal.

Of this classification the two first and most primitive divisions were (*loc. cit.* p. 262):—

- |                                                                        |                           |
|------------------------------------------------------------------------|---------------------------|
| “Sect. I. Var. du 1 <sup>er</sup> ordre. Tête prédominante incomplète. | Type <i>Sao hirsuta</i> . |
| Thorax nul ou rudimentaire.                                            |                           |
| Pygidium nul.                                                          |                           |
| “Sect. II. Var. du 2 <sup>e</sup> ordre. Tête distincte incomplète.    | Type <i>Trinucleus</i>    |
| Thorax nul.                                                            | <i>ornatus</i> et tous    |
| Pygidium distinct, incomplet.                                          | les <i>Agnostus</i> .”    |

With modern ideas of trilobite larval morphology, the most posterior segment of the trilobite shield is considered to lodge the growth-centre of most, if not all, the preceding segments, and, as such, is a very early and important structure of the trilobite, recognizable in the most early larvæ, so the definition of Section I. would nowadays read:—

Cephalon predominating.  
 Thorax not seen.  
 Pygidium rudimentary.

It would, in fact, hardly differ from that of Section II. One is therefore left to infer, from the description and figures of the early larvæ of Section I., what the section really comprised.

Beecher (1895, pp. 167–169) founded the “protaspis” (“an early larval type apparently so characteristic of all trilobites”) on the characters shown

by Section I. of Barrande's classification. He defined "the simple characters possessed by the protaspis as" (Raymond-Beecher, in Zittel, 1913, p. 703):—

"Dorsal shield minute, not more than 0.4–1.0 mm. in length; circular or ovate in form; axis distinct, more or less strongly annulated and limited by longitudinal grooves; head portion predominating; axis of cranium with five annulations; abdominal portion usually less than one-third the length of shield, axis with from one to several annulations; pleural portion smooth or grooved; eyes when present anterior, marginal or sub-marginal; free cheeks, when visible, narrow or marginal."\*

Beecher (1895, p. 169) designated early, middle, and late protaspis stages as ana-, meta-, and para-protaspis respectively. No detailed diagnosis of these sub-divisions was offered, but the descriptive notes accompanying figures of the various larvæ showed, to some extent, Beecher's conception of the terms. It seems, however, difficult to state general characters by which a particular sub-division can be recognized, for Beecher's figure of the meta-protaspis of *Ptychoparia kingi* Meek (*loc. cit.* pl. viii. fig. 6) shows an apparently less advanced structure than the ana-protaspis of *Dalmanitina socialis* (Barrande), pl. ix. fig. 8; this would be in keeping with Beecher's not unwarranted assertion that acceleration occurred within the ana-protaspis stage of different trilobites as evolution proceeded (1895, p. 180).

The earliest recorded larval stage of *Arges* (*Corydocephalus*) *consanguineus* Clarke was considered to be a para-protaspis (*loc. cit.* p. 173), and the earliest stage of *Trinucleus ornatus* Sternb. post-protaspidean (*loc. cit.* p. 176), though, judging from the figures of both, the cephalon and pygidium are "distinct" in the sense used by Barrande. It seems, therefore, by no means easy to decide exactly what criteria were adopted by Beecher for dividing the protaspis from the later stages.

Raw (1925, p. 226) interprets the "Protaspis Period" as ending with the "development of a definite transverse suture sub-dividing the dorsal shield."

Just as the exact distinction between a suture and a groove may frequently be difficult to determine when dealing with small larvæ, and more difficult still when dealing with published figures of these, so it seems that the dividing-line between the protaspis and the later stages has been difficult to determine in the past, unless, of course, disarticulated specimens have been found, or specimens showing an unmistakable 'pygidial' articulation.

In the case of *Shumardia pusilla* the term protaspis is here used only for those larvæ which have no free thoracic segments and have no articular surface yet developed on the transitory pygidium.

Raw, in his illuminating paper (1925), does not adopt the terms ana-, meta-, and para-protaspis for sub-divisions of the Protaspis Period, and this

\* Concerning this definition it should be observed that recent writers, Swinnerton (1915) and Warburg (1925), have queried the evidence for sub-marginal eyes and for facial sutures in any protaspis, with the possible exception of the facial suture in *Ptychoparia kingi* Meek. Warburg also maintains (*loc. cit.* p. 32) that the larval ridge is a protaspidean character in the more primitive trilobites.

practice will be followed here, as will be, with some modification, the adoption of the Cobbold-Raw terms "Meraspid" and "Holaspid" (Raw, *loc. cit.* pp. 226-227).

Raw's objection to the use, in arthropod ontogenetical studies, of terms borrowed from human development is upheld here, in the case of Beecher's terms: nepionic, neanic, ephebic, and gerontic\*.

The *Meraspid Period* (the nepionic and neanic stages of Beecher's usage) is accepted here as beginning with the division of the protaspis into a cephalon which articulates upon a transitory pygidium, and the period "covers the successive appearance of each of the thoracic segments."

This *Meraspid Period* is divisible into definite steps for which Barrande's term *Degree* is adopted, each degree characterized by the number of *free* thoracic segments, and numbered accordingly; the earliest *Meraspid Degree* is *Degree 0*, since no thoracic segments have yet been freed. The last thoracic segment to appear in *S. pusilla* is the sixth, so the final degree of the *Meraspid Period* will be *Degree 6*.

The *Holaspid* (or 'complete shield') *Period* is used here for the stages including and following that in which complete post-cephalic segmentation has been attained, and would include those stages designated by Beecher neanic (*pars*), ephebic, and gerontic. (This usage differs by definition from that given by Raw, but this modification is needed if the term "*Holaspid*" is to retain its literal meaning.)

## II. OBSERVATIONS ON THE MATERIAL COLLECTED.

### PROTASPID PERIOD. (Pl. 14. fig. 1, & Pl. 15. fig. 10.)

An internal cast of an almost circular dorsal shield (Spec. 81) has been found in close association with later larval stages of *S. pusilla*.

Its general characters are:—

Length 0.24 mm., maximum breadth 0.23 mm.; very convex from front to back and from side to side; trilobed, axial portion raised and extending practically the whole length of the shield. Shows partial division into cephalic and pygidial portions by a weak transverse groove extending across the axis and the more dorsal parts of the cheeks in a region 0.15 mm. from the anterior margin.

*Cephalic portion*: Anterior margin notched centrally by a deep and wide crescent-shaped depression, the outline of which is convex posteriorly; laterally the cephalic portion is not differentiated from the 'pygidial portion' of the shield.

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\* In this connection it may be observed that objection has been taken to the use of such terms as "thorax" and "suture" for Trilobite structures, which are by no means homologous with the structures for which those terms were instituted by zoologists. It is considered, however, that these two terms are too well fixed among Trilobite morphologists for supersession.

*Glabella* of four lobes, of which the anterior is the largest; widest in the 'frontal lobe,' but narrowing forwards to terminate antero-medianly as an obtuse angle on the front slopes of the cephalon.

*Glabellar furrows*: Three straight continuous transverse furrows of which the most anterior is weakest.

*Axial furrows* definite, though weak in front of the broadest part of the glabella (*i. e.* the central portion of the frontal lobe); quite prominent behind this region.

*Cheeks* smooth.

*Pygidial portion*: Laterally and posteriorly the outline is that of an arc of a circle.

*Axis* slightly raised, of two segments feebly separated; apparently grades posteriorly into the post-axial portions of the shield, but general convexity of the surface renders detail obscure.

*Lateral portions* of 'pygidium' smooth.

### Remarks.

The wide frontal lobe terminating anteriorly in an obtuse angle is a diagnostic character paralleled in the later stages of *S. pusilla*; the small size of the larva and its association on a surface 13 sq. cms. in area with 5 complete larval specimens and 3 isolated cephalae of *S. pusilla* and with remains of no other recognizable trilobite support the relegation of this protaspis to *S. pusilla*.

The pre-glabellar crescent-shaped depression is correlated with the median pre-glabellar groove of the earliest stages of Degree 0 and with the gently notched anterior margin of all later stages.

### MERASPID PERIOD.

**Degree 0.** (Pl. 14. fig. 2, & Pl. 15. fig. 11.)

Measurements obtained from observations on 7 complete specimens:—

Total length .....	0·31–0·50 mm. (the average specimens approximate 0·37 mm.).
Length of cephalon.....	0·20–0·28 mm.
Length of transitory pygidium	
of 3 segments .....	0·11–0·16 mm. (6 specimens).
of 4 segments .....	0·22 mm. (1 specimen).

The smallest specimen of this stage (Spec. 219) is 0·31 mm. in length and has a line of flexure between the cephalon and the transitory pygidium. The greatest breadth of the shield is, as in later stages, at the posterior end of the cephalon (here 0·32 mm.).

*Cephalon* very convex, trapezoidal in outline, broader than long. The pre-glabellar field lies almost in a vertical plane and is marked by a weak median groove which produces a gentle notching of the almost straight anterior margin of the shield. (The groove is only visible in the smallest specimens.)

*Glabella* separated laterally from the cheeks by strong axial furrows which run backwards and inwards from the widest part of the glabella, which occurs in the first lobe; in front bounded by faint but distinct furrows, terminating in an obtuse angle, the apex of which forms the base of the pre-glabellar groove.

The segmentation is obscure, but two transverse grooves or furrows appear to occur posteriorly, and a third more anterior furrow is just indicated behind the front segment as a pair of lateral pits. The wide anterior lobe already shows a slight differentiation of the "eye-like" \* lateral lobes visible in the adult. The occipital ring appears to bear a median tubercle, which, however, cannot be traced in the later stages.

The glabella is more inflated than the rest of the cephalon, and maximum inflation henceforward occurs in the second and third lobes.

*Cheeks* smooth, produced postero-laterally into short backwardly-directed genal spines.

*Transitory pygidium* less convex than the cephalon; margins are damaged, but a post-axial depression is clearly seen.

*Axis* bounded laterally by well-marked axial furrows which converge posteriorly to continue as the post-axial depression. Anteriorly the axis is separated by a transverse furrow from an articular-facet, which really forms part of the pygidium, but is usually partially hidden in this Degree by the occipital ring of the cephalon, and at later stages by the most posterior ring of the thoracic segments †. Composed of three axial rings.

*Lateral portions or lobes* divided by two weak grooves into three pairs of pleuræ, which in Specimen 219 are not clearly preserved.

A specimen 0.34 mm. in length (Spec. 230) shows a transitory pygidium where the post-axial depression has strongly notched the posterior margin, and the lateral portions of the shield show that each individual of the three pairs of pleuræ terminates laterally in a short and weak backwardly-directed spine. The first pleuræ are the strongest, having greater length and breadth and more prominent spines than have the more posterior segments.

As growth proceeds, the 3rd segment of the pygidial axis becomes more prominent (Specs. 56 and 400), and in the largest specimen of this stage (Spec. 25) an abnormal fusion occurs, for four segments are retained in the transitory pygidium; four axial rings are seen and four pairs of spined pleuræ.

## MERASPID PERIOD.

**Degree 1.** (Pl. 14. fig. 3, & Pl. 15. fig. 12.)

*Detachment of the first free thoracic segment.*

Measurements gathered from observations of 8 complete specimens:—

Total length .....	0.47-0.52 mm.
Length of cephalon .....	0.25-0.28 mm
Length of thorax of 1 free segment .....	0.05-0.07 mm.
Length of transitory pygidium of 3 segments .....	0.16-0.18 mm.

From the beginning of this degree onwards through the life-history, the depressed-ovate outline of the adult becomes more and more perceptible, for the dominant growth increase is in the direction of greater length coupled with a tendency for greater post-cephalic segmentation.

*Cephalon:* Size and general convexity have increased, but the genal spines show no appreciable increase in strength.

\* Mon. Brit. Cambr. Trilobites, pt. ii. p. 41 (1907).

† The pygidial and thoracic length measurements do not include these articular facets.

*Glabella*: Except in the case of the occipital furrow it is rare to find continuous transverse glabellar furrows in this and in succeeding degrees; these are usually isolated as lateral furrows lying in the axial furrow on the sides of the glabella, and except in the best preserved specimens the second pair of furrows is difficult to see.

*Thorax*: The free segment is provided anteriorly with an axial articular-facet which simulates an axial ring by its convexity, but it is semi-lunar in outline and has but weak 'pleural' developments—these are thin step-like facets which are closely fused with and form part of the thoracic pleuræ. The axial articular-facet is separated from the axial ring of the thoracic segment by a transverse furrow much like a normal inter-segmental ring furrow.

*Axis* of one ring, raised above the level of the pleuræ, and convex from side to side.

The *pleuræ* run straight out from the axial furrows and are parallel-sided for two-thirds of their length; they are then transversely truncated, diminish in strength, and turn sharply backwards to end as weak spines. They show a prominent ridge running parallel to the front margin and ornamented by a small central tubercle.

#### *Transitory pygidium*:

General outline similar to that in Degree 0, but shield shows a slight increase in length, breadth, and perhaps convexity; this last character is always, in both thorax and pygidium, less developed than in the cephalon. No specimens of this Degree have been found where the axial rings exceed three in number.

*Axis* provided anteriorly with an axial articular-facet, bounded posteriorly by a furrow and resembling in general character that seen on the free thoracic segment; such a facet occurs in Degree 0 and in all later stages.

*Lateral portions* of 'pygidial' shield usually divided by two pairs of furrows running outwards and backwards into three pleuræ, all of which terminate in fine backwardly-directed spines. Of these the third pair may show the greatest strength only when a fourth pair of very minute spines occurs posterior to them—this is seen in one of the larger specimens (Spec. 401, fig. 12). Ridges like those of the thoracic pleuræ are seen on the first two pairs of pygidial pleuræ and are best developed on the first pair.

#### *Remarks.*

In this Degree, with one possible exception (Spec. 401), the number of post-cephalic segments never exceeds that seen in the late Stages of Degree 0, but conditions differ in that, during Degree 1, one segment exists in an unfused condition.

#### MERASPID PERIOD.

**Degree 2.** (Pl. 14. fig. 4, & Pl. 15. fig. 13.)

*Development of long pleural spines on the second segment of the transitory pygidium.*

Measurements gathered from observations of 19 complete specimens:—

Total length .....	0.58–0.68 mm. (average specimen is 0.62–0.64 mm.).
Length of cephalon .....	0.29–0.34 mm.
Length of thorax of 2 free seg- ments .....	0.11–0.15 mm.
Length of transitory pygidium of 3 segments .....	0.16–0.19 mm.



*Cephalon* increased in size and convexity; axial furrows deepening; the anterior notch in the margin is less appreciable.

*Glabella*: The inflation has steadily increased and the 'eye-like lobes' show partial isolation from the frontal lobe of the glabella, by the forward development of a slight furrow continuing the general axial direction of the axial furrows; this character is visible in some specimens of Degree 1. The original axial furrows meanwhile are more impressed, up to the middle of the lateral margins of the 'eye-like lobes,' but they suddenly become shallow and continue round the anterior borders of the glabella as weak lines.

*Thorax*: The second free thoracic segment, except that it is slightly shorter, is almost a replica of the first; both segments terminate laterally in short truncated spines and both have ridges ornamented with a central row of small tubercles. In each segment the tubercles form a continuous central line, running along the pleuræ and across the axis.

*Transitory pygidium* in this Degree is always broader than in the preceding Degree, but in length it almost conforms to the measurements of Degree 1.

The average specimen shows three axial rings, though in the earlier stages the line of demarcation between the last two rings is not always very clear.

*Lateral portions* divided by interpleural furrows into three pairs of pleuræ, the first two of which are ridged, and of these ridges the more anterior pair is tuberculated, as are the thoracic pleuræ.

The pleuræ terminate laterally in backwardly directed spines of which, in well-preserved specimens, the second pair are very long, and may extend well beyond the posterior margin of the pygidium (see figs. 4 and 13).

In some of the larger specimens a fourth pair of small lateral spines is seen arising from the sides of the post-axial depression and in the largest specimen of this Degree (Spec. 150) four axial rings are seen, though the 'pygidium' is no longer than many of the shields with only three rings; it is seen, therefore, that whilst in the earliest stages of Degree 2 there are only five post-cephalic segments delineated on the dorsal shields—in later stages six occur.

#### *Remarks.*

It is noted that in the smaller specimens of this Degree, the transitory pygidium is smaller than in the largest specimen of the Degree preceding (*i.e.* Degree 1), though the total length of the fossil is somewhat greater. This character is also seen in the two succeeding Degrees.

#### MERASPID PERIOD.

##### **Degree 3.** (Pl. 14. fig. 5, & Pl. 15. fig. 14.)

*Presence of long pleural spines on the first segment of the transitory pygidium.*

Measurements gathered from observations of 19 complete specimens:—

Total length .....	0.69–0.86 mm. (average specimen 0.74–0.80 mm.).
Length of cephalon .....	0.33–0.40 mm.
Length of thorax of 3 free seg- ments .....	0.17–0.24 mm.
Length of transitory pygidium of 3 segments .....	0.17–0.20 mm. (14 specimens).
of 4 segments .....	0.21–0.23 mm. (2 specimens).

Within the growth interval represented by this Degree the cephalon loses the dominance in length that it possessed in the earlier Degrees, for in the latter stages the combined length of the post-cephalic segments exceeds that of the cephalon.

The *thorax*, in the smaller specimens, has a length roughly equivalent to that of the transitory pygidium, but in the larger specimens the thorax has the greater length. The first segment is usually longer (measured from front to back) than either of the posterior segments, and the first two segments are both broader than the third, otherwise the segments are very similar; no trace is seen of long pleural spines terminating any of the free thoracic segments.

The tubercles mentioned in the two preceding Degrees are now more evident, and are visible on all free segments; they have increased numerically, and this increase continues throughout subsequent growth.

The *transitory pygidium* is in outline more sub-quadrate and usually wider than in preceding Degrees, but it experiences, in its three segment stages, length changes similar to those in Degrees 1 and 2.

The first two segments show tuberculated ridges on their axes and pleuræ, the pleuræ show more curvature and the axial furrows are stronger than in preceding stages.

The component members of the first pair of pleuræ show a fulcrum at two-thirds of their course, where the segment is appreciably strengthened posteriorly; the pleuræ here take a right-angled bend backwards to terminate in strong straight spines which continue beyond the posterior margin of the shield.

The second pleuræ have but short denticulate spines and the third pair of spines are so small as to be rarely preserved, though they are visible in the better specimens.

In the larger specimens three pairs of lateral furrows are observed on the shield and four segments are clearly differentiated on both the axis and on the lateral portions of the transitory pygidium, though the last segment has never been observed to show spinose termination.

#### *Remarks.*

The earliest stages of this Degree show specimens having six post-cephalic segments, that is, the same number seen in the largest specimen of Degree 2; here, however, three are found free, whilst three are fused into the transitory pygidium. The number of free segments remains constant throughout the Degree, but in the later stages, as the posterior shield grows in size, a new segment is developed within it—thus seven post-cephalic segments may occur.

#### MERASPID PERIOD.

**Degree 4.** (Pl. 14. fig. 6, & Pl. 15. fig. 15.)

*Presence of long pleural spines on fourth free thoracic segment.*

Measurements \* derived from observations of 25 complete specimens:—

Total length .....	0.90–1.06 mm.
Length of cephalon .....	0.37–0.49 mm.
Length of thorax of 4 free segments .....	0.29–0.37 mm.
Length of transitory pygidium	
of 3 segments .....	0.17–0.20 mm. (6 specimens).
of 4 segments .....	0.21–0.23 mm. (15 specimens).

\* These measurements do not include those of the anomalous specimens seen in this Degree, and discussed on pp. 357 and 358.

*Cephalon* larger, but otherwise much as in earlier Degrees, with strong and wide axial furrows, which shallow off at the middle of the lateral margins of the 'eye-like lobes,' which lobes have now, by reason of the separating furrow described under Degree 2, attained quite appreciable independent inflation.

*Thorax*: The three anterior segments are very similar in general characters, and also in the short truncate character of their spinose lateral terminations; there is, however, throughout the thorax a gradual diminution in size from before backwards; the posterior or fourth segment differs in a character other than size from its antecedents, for its pleuræ are strengthened at the fulcrum and produced backwards into long straight spines which extend a little beyond the hinder margin of the transitory pygidium.

All segments bear a row of tubercles on both axis and pleuræ, and the pleural ridge of the fourth pleura follows the direction of the posterior rather than the anterior margin of the pleuræ and it appears to transgress the fulcrum obliquely to continue into the spine.

*Transitory pygidium*:

Though this shield has not yet developed a tuberculated border, and still retains a post-axial groove, its general outline and convexity (from side to side) closely simulate those of the adult pygidium.

The relation between number of segments and length is almost completely similar to that seen in Degree 3, and a further point of close resemblance is in the anterior breadth of the shields.

The *axis* shows three rings in the smaller and four in the larger specimens.

The *lateral portions* show, according to the segmentation of the axis, either two or three pairs of intersegmental furrows; where three pairs of furrows are developed, the first two pairs are the deepest, especially so laterally. The lateral margins are entire, except for the slight projecting terminal spines of the pleuræ of the first segment. The terminations of the second pleuræ are visible but show no appreciable projection beyond the contours of the shield.

In this Degree every pygidial segment is provided with a row of tubercles, and in some large specimens a pair of short rows of tubercles on the sides of the post-axial groove suggest the presence of a rudimentary fifth segment.

*Remarks.*

As in Degree 3, the small transitory pygidium of the early stages has a lesser length and a smaller number of component segments than in the Degree preceding it, whilst the thorax has increased its length and number of segments. A further resemblance is that in both Degrees, though the thorax retains a constant number of segments for the particular Degree, the transitory pygidium adds a new segment to the number present at the beginning of the Degree.

Were it not for this abundance of specimens of Degree 4 showing developmental characters in keeping with the series treated in this paper, certain anomalous specimens of *Shumardia*, also having but four free thoracic segments, might have seriously disturbed the smoothness of the developmental history.

Five such specimens are known: two from H.M. Geol. Survey Collection (J. Rhodes) were figured by Lake and Raw (1907), one, Spec. RR 2296, as pl. iv. fig. 2, and the other, Spec. RR 2286, as pl. iv. fig. 4; three specimens having characters similar to these, occur in our own collection, and of these two have counterparts.

The total lengths of these specimens vary from 1·00 mm. (RR 2286) to as much as 1·40 mm. (Spec. 51, Pl. 15. fig. 16). All show but four free thoracic segments, of which the third *and* fourth pairs of pleuræ bear long spinose terminations—one specimen even shows long backwardly-directed spines on the second pleura. The preservation of the fossils is by no means perfect, but it would appear that all specimens probably had long spinose pleuræ, and that the fourth pair were not dominant in length or strength since both the third and fourth pleuræ extend considerably beyond the hinder margin of the pygidium.

The pygidium has an aspect different from that of typical specimens, for the axis seems to be more truncated posteriorly; the lateral portions show less convexity, and have few signs of segmentation, though this last character may be due to inferior preservation.

The cephalon echoes the spinose tendency of the thoracic pleuræ and shows long thin genal spines running in an axial direction (Spec. 53).

The glabella is separated from the cheeks by axial furrows, which do not appreciably weaken anteriorly as in early and late stages of *S. pusilla*, and, furthermore, the glabella shows but a slight widening at the 'eye-like lobes,' and retains an almost constant breadth.

Excluding the consideration of these five specimens, the larval history of *S. pusilla* would be perfectly normal, but if these must be accepted as members of the *S. pusilla* developmental series, then, at this degree, there occur both normal individuals and individuals showing unique characters in the cephalon, thorax, and transitory pygidium. Furthermore, the anomalous characters are of sudden appearance and are apparently peculiar to a minority of specimens in Degree 4. The number of good specimens examined in this and other Degrees leaves little doubt in the mind of the writer that the anomalous specimens are not peculiarities of preservation, but that their characters form definite variations from the typical series and the specimens are therefore worthy of separate varietal or even specific recognition. It is not, however, proposed to give them specific description until more and better material has been collected.

#### MERASPID PERIOD.

**Degree 5.** (Pl. 14. fig. 7, & Pl. 15. fig. 17.)

*Appearance of tuberculated pygidial border.*

Measurements derived from observation of 13 complete specimens:—

Total length .....	1·26–1·67 mm.
Length of cephalon .....	0·56–0·69 mm.
Length of thorax of 5 free segments .	0·43–0·60 mm.
Length of transitory pygidium	
of 4 segments .....	0·25–0·28 mm. (7 specimens).
of 5 segments .....	0·31–0·38 mm. (6 specimens, usually below 0·37 mm.).

*Cephalon:*

In this and in the following stages the cheeks show posteriorly a thin step-like depression which appears to be a lateral and posterior continuation of the deep and wide axal furrows.

In these stages the greater convexity of the cephalon renders it particularly liable to compression, and except in the best preserved specimens length and breadth measurements are unreliable.

The *Thorax* has acquired a free segment posterior to that bearing the long pleural spines (which are now seen to be hollow), but in this segment the pleuræ terminate in short spines running backwards and outwards, much like those of the three anterior segments, rather than directly backwards as in the fourth pleuræ.

In some specimens the fourth pleural spines take origin from a point on the pleuræ more dorsal than is usually the case, and the spines then appear to lie above and along the surface of the animal rather than along its sides.

*Transitory pygidium:*

The four-segment stage of the 'pygidium' is always longer and broader than in the four-segment stage 'pygidium' of preceding Degrees.

It and its descendant, the five-segment stage 'pygidium,' differ from their predecessors, since they have a border surrounding the posterior and the greater part of the lateral portions of the shield.

This border is separated from the more dorsal regions of the 'pygidium' by a weak border furrow, and is ornamented with a single row of tubercles similar in character to those of the thoracic and 'pygidial' segments. Anteriorly the border terminates before reaching the first 'pygidial' pleuræ, which project laterally as short terminal spines (see fig. 7).

These spined pleuræ in the later stages show signs of incipient lateral detachment.

The post-axial groove seen from Degree 0 onwards has now become obsolete, and the axis extends almost as far as the border-furrow. A relic of the post-axial groove occurs as a notching of the posterior margin of the shield, a character seen throughout subsequent development and somewhat comparable with the anterior notching of the cephalon.

*Remarks.*

The maximum number of post-cephalic segments definitely observed in Degree 4 was eight, and the minimum number seen in Degree 5 is nine; it seems, therefore, that the transitory pygidium has gained impetus in the moult occurring between Degree 4 and Degree 5, and has added a segment to the thorax as well as adding one to itself; unless, of course, a gap occurs in the collected series where five free and three fused segments should be visible.

The thorax needs but one segment for its completion, and it is noteworthy that but one segment of the transitory pygidium shows any tendency towards lateral separation.

There is a specimen (Spec. 60, Pl. 15. fig. 18) of Degree 5 which, though typical in other respects, shows a curious asymmetry in the development of the long pleural spine.

The fourth thoracic pleura on the left side shows a normal long backwardly-directed spine, whilst on the right side the fourth pleura appears to have atrophied, and from a point rather less than half-way along its

normal course it fuses with the fifth pleura and a short stout compound lateral termination results.

The third pleura of this side is, however, abnormally strengthened laterally, and forms a spine comparable in length and strength with that usually carried by the fourth pleuræ.

It should be mentioned that the third pleura of the left side is normally developed.

These abnormal conditions of the third, fourth, and fifth pleuræ of the right side of the animal may possibly have followed upon an injury to the fourth at an early stage.

#### MERASPID PERIOD.

**Degree 6.** (Pl. 14. fig. 8, & Pl. 15. fig. 19.)

*Thorax complete. Pygidium incomplete.*

Measurements derived from observations of 6 complete specimens:—

Total length . . . . .	1.81-2.43 mm. (the earliest specimens are too imperfect to give reliable complete measurements).
Length of cephalon . . . . .	0.73-0.94 mm. (ditto).
Length of thorax of 6 free segments . . . .	0.67-1.00 mm.
Length of pygidium of 4 segments . . . . .	0.30-0.49 mm.

*Cephalon* very much of adult aspect, with deep axial furrows, which weaken at the centre of the lateral margins of the 'eye-like lobes' and continue forwards to delineate faintly the obtuse-angled termination of the glabella.

*Glabella* strongly inflated, maximum inflation in the third visible lobe.

The glabellar furrows, apart from the continuous occipital furrow, are not very prominent, but in this and the later stages, when characters become more accentuated, the second pair of lateral furrows become progressively more prominent.

*Cheeks*, as in preceding stages, smooth.

#### *Thorax:*

With the addition of the sixth segment, the thorax just exceeds the length of the cephalon and now becomes the dominant length of the body.

The sixth or posterior segment closely resembles the fifth, having a short outwardly backwardly-directed spine.

It is seen that the fulcra of the last three free segments occur progressively nearer in, from before backwards, whilst the first three segments have their fulcra at an almost uniform distance from the axial furrows.

*True pygidium* sub-quadrate in outline, margin entire, notched gently post-axially.

The tuberculated border continues anteriorly to include the tips of the first pygidial pleuræ.

*Axis* of four tuberculated and well-arched rings, of which the last shows a gradual increase in size as development proceeds.

*Lateral portion:* Three pairs of lateral interpleural furrows, continuing only to the border furrow and themselves diminishing in individual strength posteriorly, separate four pairs of pleuræ, each with tuberculated ridges,

*Remarks.*

The minimum number (*i. e.*, ten) of post-cephalic segments seen in this Degree is the maximum number seen in Degree 5, and the pygidium in the early stages of this Degree is shorter than the transitory pygidium of Degree 5, so that it seems that the sixth thoracic segment is freed at the expense of the length development of the transitory pygidium as were the fourth, the third, and the second.

HOLASPID PERIOD. (Pl. 14. fig. 9, & Pl. 16. figs. 20 and 21.)

*Completion of segment-formation.*

Measurements derived from observations of 5 complete specimens (there are many complete specimens from which no reliable measurements can be taken because of compression) :—

Total length .....	3.29-4.91 mm.
Length of cephalon .....	1.27-1.81 mm.
Length of thorax of 6 segments .....	1.35-2.02 mm.
Length of pygidium of 5 segments ...	0.67-1.08 mm.

The compression mentioned above is particularly noticeable in the anterior portions of the cephalon, and when this occurs the obtuse-angled termination of the glabella is flattened, and not infrequently a continuous crack is developed parallel to the margin of the cephalon—this crack may run across the front of the glabella or may have a more marginal position.

The dominant characters seen in this, the adult period, are a general increase in size and an emphasis of pre-existing characters ; this emphasis is particularly noticed in the furrows of the glabella.

The 'axal' furrow, partially separating the 'eye-like lobe' from the frontal lobe, has become concave outwards, but it never reaches the anterior margin of the lobe.

The lateral furrows separating the lobes lying between the frontal lobe and the occipital ring are in large specimens sufficient to cause a slight but definite lateral lobation.

The thoracic segments have each a row of tubercles, which, since their formation, have been steadily increasing in number as the segments increased in breadth ; in this Period a second row of smaller tubercles is developed on the pleural ridges in front of the preceding row. These new tubercles are first seen on the lateral portions of the pleuræ, but in the larger specimens the first three pairs of pleuræ have two complete rows. Suggestions of this second row of tubercles is seen in some specimens of the stage immediately preceding the Holaspide Period.

The long spines of the fourth pleuræ have been steadily growing in length to extend well beyond the pygidium, and are frequently "as long as the thorax and tail combined" (Raw & Lake, 1907, p. 41).

*The Pygidium.*

The fourth pygidial segment of Degree 6 (Meraspid Period) has developed a definite dividing furrow which stretches across the shield, and the adult pygidium shows five segments \*. Only in the larger specimens does the last ring bear tubercles, but the short corresponding pleural ridges carry a small number in all specimens. The ridges of the more anterior pleuræ show traces of a second antero-lateral row of tubercles such as are visible in the thoracic segments.

An almost vertical doublure lying below the border of the pygidium is seen in the larger specimens (fig. 20), and this gives an appearance of thickness to the pygidial shield.

Further notes on the morphology of the adult are to be found in the description given in the *Mon. Brit. Cambr. Trilobites*, 1907, pt. ii.

## III. CONCLUSIONS DERIVED FROM THESE OBSERVATIONS.

(i.) *Progressive Growth of the Dorsal Shield.*

From the foregoing notes and from the series of figured reconstructions (Pl. 14) it will be seen that an almost circular dorsal shield 0.24 mm. in diameter, gradually attains a more depressed-ovate outline and reaches a maximum length which probably exceeds 4.91 mm.; that is, the length measurement is multiplied by a number slightly over 20. This change is accomplished by:—

(a) A fairly constant growth of an already formed cephalon, the very early stages of whose growth leave here no discernible record.

(b) Growth of the existing post-cephalic segments and by the formation of further post-cephalic segments which, if all such segments are treated as a unit, shows always an increase in the direction of greater relative length rather than breadth. The small amount of evidence available shows that, excluding the hindmost and also the most anterior of the post-cephalic somites, each segment, when formed, rapidly acquires the length, and to a less extent the breadth, of its preceding segment and then grows more or less in unison with that segment. When all the post-cephalic segments are formed their general growth is fairly constant.

These subdivisions of the progressive growth of the trilobite will now be considered separately.

\* Though the *Mon. Brit. Cambr. Trilobites*, 1907, pt. ii., figures at least one specimen showing five pygidial segments (pl. iii. fig. 18) in the text, it is stated, p. 41, that the form shows "Tail . . . segments four in number . . . ."



*(a) Growth in the Cephalon.*

In no specimen have structures which can be identified as eyes been recognized in the cephalon, nor have eye-lines or facial sutures been observed.

The 'cephalic portion' of the protaspis described here shows anterior paired projections, which may have lodged short spines or conceivably some sensory organ. It is postulated that the depression between these projections subsequently became filled, leaving, in the stages immediately following, a pre-glabellar groove which quickly became obsolete; a slight median notch is visible in the anterior margin of the cephalon through the life-history, but it becomes progressively less visible as growth proceeds.

After the Protaspis Period is passed the cephalon becomes trapezoidal in outline, and this outline is retained through the later stages with but slight modification.

In Degree 0, the cephalon has a convexity greater than that of the post-cephalic regions, and this dominant convexity is retained or even increased throughout growth; the greater convexity of the cephalon carries with it a deeper impressing of the axial furrows.

The ratio of length to maximum breadth always approximates to that of 2:3, and the region of maximum breadth is always at the posterior end of the cephalon, except in the Protaspis Period, where it is rather more anterior in position.

The cheeks of the cephalon are always smooth, and are produced posteriorly to end in genal spines, which are first seen in the specimens of Degree 0, and though always present in later Degrees they are stouter and less elongated than in this Degree.

The glabella of the Protaspis cephalon is divided into four glabellar lobes, of which the anterior is the widest and narrows forwards to end in an obtuse angle.

A 'quadrilobation' is recognizable in all later stages, but the occipital ring or lobe is the only component clearly defined by a continuous bounding furrow in all stages, for the other glabellar furrows, after the early stages, are isolated as obscure lateral furrows.

The wide anterior lobe even in Degree 0 shows incipient local differentiation into 'eye-like' lateral lobes, and as development proceeds these are partially divided from the rest of the lobe by 'axal' furrows, which are first seen in Degree 2 and subsequently become more evident.

In Degree 0 the glabella occupies about 19/20ths of the cephalon length (measurements taken along the axis), and as growth proceeds the fraction diminishes till, in Degree 6 and later stages, it becomes about 9/10ths, but the exact point of the anterior termination of the glabella is not always easy to determine, and a certain apparent variation may occur in really well-preserved specimens of the same Degree.

Before leaving the subject of the cephalon growth, a few remarks will be made concerning the relative growth in length of the cephalon compared with that of the composite structural unit, the transitory pygidium, and with the thorax.

In the Protaspid Period the cephalon has the dominant length of the dorsal shield, but this dominance is shortly challenged by the post-cephalic elements, for in late stages of Degree 0 the transitory pygidium itself occupies 44 per cent. of the dorsal shield. In Degree 2, the transitory pygidium, together with the two free thoracic segments, equal and, in later stages of the same degree, exceed the length-measurement of the cephalon, whilst in Degree 6 the thorax alone, now with its full number of segments, equals, and in later stages slightly exceeds, the cephalon length, a character retained through the later stages of the life-history.

In an adult specimen (Spec. 76, Pl. 16. fig. 20) length-measurements were :—

Cephalon 1.35 mm., thorax 1.43 mm., pygidium 0.81 mm., which works out to a percentage length ratio of cephalon 37.6 per cent., thorax 39.8 per cent., pygidium 22.5 per cent.

(b) *The Origin, Subsequent Movement, and Growth of the Post-Cephalic Segments.*

The development of *S. pusilla* shows that this trilobite conforms to the trilobite type first described by Barrande (1852) in the development of *Sao hirsuta* and other forms, where a few post-cephalic segments are first seen fused into a transitory pygidium. As growth proceeds, these segments are later freed anteriorly one by one, to become freely articulating segments; the transitory pygidium meanwhile grows more segments, which are released in turn until the thorax reaches its full complement of segments and the pygidium completes its growth.

The addition of segments to the transitory pygidium during the course of a particular Degree, and the arrest of segment formation during the moult, where the thorax acquires a 'new' segment, was a phenomenon frequently observed in the course of development of *Sao hirsuta*. It has been described here in *S. pusilla* during Degrees 2, 3, 4, and 6.

A further interesting point is that in Degree 2 a segment possessing long backwardly-directed pleural spines appears as the second 'fused' segment of the transitory pygidium—that is, of the five (and, in the later stages, six) visible post-cephalic segments this long-spined segment is the fourth.

In Degree 3, a similarly spined segment occurs as the first or more anterior of the segments composing the transitory pygidium—that is, the only segment showing long pleural spines is again the fourth post-cephalic segment.

In Degree 4, the fourth post-cephalic segment is freely articulating, forms the most posterior segment of the thorax, and it bears long and strong pleural spines.

Throughout the later stages of development, well-preserved specimens invariably show that the fourth post-cephalic pleuræ terminate in long backwardly-directed spines, and, with one abnormal specimen as exception (*vide* pp. 359 and 360), long spines are never observed on any other segment; so it can be considered that this fourth post-cephalic segment is distinguished from any other by its long pleural spines.

In the average specimen of Degree 1 there are four post-cephalic segments only, and long spines are never developed on the last segment, though in the specimen shown in fig. 12 fairly strong spines occur on the pleuræ of the fourth post-cephalic ring; since, however, a short pair of spines occurs behind these long spines, it seems that indications of five pairs of pleuræ are seen, and only four axial rings—*i. e.*, the fourth post-cephalic segment of the early stages of the Degree shows incipient lateral division into two segments, a condition not infrequently seen in the last segment of later Degrees.

The first definite appearance of the long spines is in Degree 2, and they are here found on the pleuræ of that segment immediately preceding the last axial ring. Accordingly one may accept that the fourth post-cephalic segment is first recognized with long spines when in the region immediately in front of the last segment of the trilobite body, and as ecdysis and consequent growth proceeds, this segment is moved forwards, and new segments are formed behind it until the adult number appear.

It is considered, therefore, that in the case of *Shumardia pusilla* fairly conclusive evidence is advanced in support of the law governing the origination of segments in Arthropoda, which law Ray Lankester enunciated (1904, pp. 536-537) as the 9th Law of Metamerism:—

"that new somites or segments are added to a chain consisting of two or more somites by growth and gradual elaboration— what is called 'budding' of the anterior border of the hindermost somite. This hindermost somite is therefore different from all other somites and is called the 'telson.' However *long or short or heteromized the chain may be new metameres or somites are only produced at the anterior border of the telson* \* except in Vertebrata."

It is by no means claimed that *Shumardia pusilla* is the first trilobite used to demonstrate the truth of Lankester's Law, for Beecher in 1896 had already put forward an hypothesis concerning the mode of origin of segments in *Triarthrus becki*; from a study of the appendages of this trilobite he found that such appendages are largest and longest on the anterior part of the thorax and diminish regularly in length and strength to the posterior end of the pygidium, and he was able to conclude that

"In *Triarthrus* . . . . no pair of limbs had an excessive physiological importance over any other pair or series of pairs, and increase progressed regularly by the addition of new members in front of the anal segment" (*loc. cit.* p. 196).

\* The italics are inserted by the present writer.

Raymond (1920<sup>s</sup>, p. 68) elaborated this hypothesis, arguing :—

“that if a new segment were introduced at a moult in front of the pygidium, that segment would probably have less fully developed appendages than those adjacent to it and so make a break in the regular succession. The condition of the appendages corroborates the evidence derived from the ontogeny of the pygidium and proves that new segments are introduced at the same growing point as in other Arthropods.”

No exception to the fact that thoracic segments are budded forwards from the transitory pygidium has yet been described—the fact has even been considered as proven by such writers as Barrande, Beecher, Raymond, Warburg, and Raw, to cite but a few.

It is perhaps perplexing, therefore, that this fact has not been directly applied to the solution of the problem revived recently by Raymond concerning the morphology of the Agnostidæ. He states (Geol. Mag. 1920, p. 23) that Wahlenburg, Dalman, Brown, and Hisinger

“used an orientation the reverse of that now accepted . . . . In the accepted position every species” (of *Agnostus*) “has a tubercle on the median line of the pygidium \*.”

In 1924 (Report of Vermont State Geologist), however, Raymond definitely commits himself to this unorthodox view, for he describes and figures as cephalæ of Agnostidæ what most modern authors would consider as pygidia and *vice versa*; this, because of the finding of a specimen of *Agn. insuetus* Raymond, showing lines resembling facial sutures on the shield, which has a median axial tubercle and a pair of lateral spines (i. e., the pygidium of modern usage).

Judging from the figure (*loc. cit. sup.* Pl. xii. fig. 2) the lines appear to the present writer too asymmetrical to be interpreted as facial sutures; furthermore, definite evidence exists in other species of Agnostidæ that the shield which would normally be considered a pygidium propagates segments forward from itself when in the transitory condition.

Five of the six species of *Agnostus* figured on Pl. 49 of the ‘Système silurien du centre de la Bohême,’ 1<sup>ier</sup> Partie and described in the text (pp. 901–911), are each treated and figured as independent developmental series showing stages from Degree 0 to the adult. These species, and a species in our own Shineton Shale collection, *Agnostus callavei* Raw, clearly show that the commonly accepted pygidium is the shield which propagates free segments forwards.

The function of the transitory pygidium to bud segments anteriorly is, undoubtedly, of fundamental importance, and unless the process for the development of new segments in the Agnostidæ is entirely different from that of all other Arthropoda, the Agnostid pygidium must remain in the orientation accepted by Angelin, Barrande, and Salter.

\* The italics are those of the present writer.

(ii.) **The Relation between the Transitory and True Pygidia.**

Judging from the characters seen on the dorsal surfaces of these two shields in *S. pusilla*, the most apparent difference is, that whilst the true pygidium has a tuberculated border posteriorly and laterally which includes or truncates the side terminations of *all* the pygidial pleuræ, the transitory pygidium in the early stages has no such border, the pleuræ being separated laterally; the shield shows, moreover, spinose lateral points, each of which corresponds to the pleural termination of a segment. In Degree 5, however, the transitory pygidium has a tuberculated border, but this does not include or truncate the pleural termination of the first segment of the shield.

The presence of transitory pygidial segments with spinose lateral terminations is the outward and visible sign in *S. pusilla* that such segments will retain these spines in the adult condition when they exist as freely articulating thoracic segments. Except for the telson, from Degree 0 to the early stages of Degree 3, no segment retained in the adult pygidium of this species ever shows lateral spinose terminations. It must be remembered that until the later stages of Degree 3, when seven post-cephalic segments are seen, the telson still possesses elements which subsequently develop into spined thoracic segments: thus one accounts for a laterally spined telson in the early stages.

The formative zone, which apparently produced the thoracic segments, also produced the pygidial segments, and is still active when the true pygidium exists as such, for a new segment is added in the moult between Degree 6 and the Holaspide Period by the fission of the pre-existing terminal segment of the shield (see p. 362). The posterior shield of any trilobite differs morphologically from the thorax, since the component segments are ankylosed dorsally in such a manner that no hinge is developed between them, though from the work of Beecher, Walcott, and Raymond, it would seem that in the adult pygidium the segments are quite independent ventrally, each having its own appendages. This posterior shield has in *S. pusilla* an anterior axial articular-facet which from Degree 0 onwards forms an articulation with the element of the trilobite lying in front.

The formative zone in the posterior shield is apparently lodged in the terminal segment or telson (*vide* pp. 365 and 366), but it is seen that each successive segment occupying the most anterior position in the shield has a new element, namely, an axial articular-facet, and probably also flexor and extensor muscles. These elements are either newly formed by an independent growth-centre, or, as seems more likely, were present in a rudimentary condition when the segment was split away from the telson, and became truly functional only when the segment reached the fore-part of the pygidium. If this segment is freed into the thorax, posterior tergal fusion is lost and the segment articulates with the pygidium.

Raymond (1920<sup>2</sup>, pp. 133-137) has demonstrated that in all trilobites of which the early developmental history is known, the (transitory) pygidium attains its maximum relative development late in the stage which is here considered Degree 0, and from then onwards throughout the Meraspid Period, whether the adult pygidium be small or large, the thorax grows at the actual expense of the pygidium.

*S. pusilla* forms no exception to this generalization, for in the largest specimen of Degree 0 the transitory pygidium occupies 44 per cent. of the total length of the dorsal shield, whilst, with slight fluctuations as successive thoracic segments become freed from fusion, the relative length decreases and the adult pygidium occupies but 22.5 per cent. of the whole shield length.

From the constancy with which this dorsal fusion of post-cephalic segments occurs, it seems that it must be of some functional significance in trilobites, and a general tendency is noted in certain families for the attainment of a comparatively large pygidial shield in the adult; the shield takes various forms and apparently evolves along different lines (*e.g.*, Asaphidæ, Agnostidæ, Phacopidæ, Goldiidæ), and so offers evidence of "convergent evolution" and possibly of what some writers term "orthogenesis."

Of the functions of the pygidium it seems evident that a shield conformable to the shape of the cephalon would complete the protection of the ventral surface of the trilobite on enrolment. Many specimens of *S. pusilla* are found enrolled and, as Raw (Raw and Lake, 1907, p. 42) observes, the axis of enrolment is between the third and fourth thoracic segments, so the pygidium, aided by the long spines of the fourth thoracic pleuræ, fairly effectively protects the under surface of the cephalon.

Raymond (1920<sup>2</sup>, pp. 72, 73, & 99) has adduced considerable evidence that the pygidium has a possible function other than protection, for he argues that a study of ontogeny, phylogeny, and musculature of trilobites shows that the pygidium was used as a swimming organ, and Swinnerton (1923) accepts this evidence.

It seems reasonable to suppose, however, that to whatever function the transitory pygidium of Degree 0 in *S. pusilla* adapted itself, whether protective or swimming, or both, the adult pygidium probably had a similar function, despite its relative decrease in size.

#### IV. GENERAL SUMMARY.

This paper is concerned with the developmental history of the small, apparently blind, Tremadocian Trilobite, *Shumardia pusilla* (Sars), which occurs as a zone fossil in the Shineton Shales of Shropshire. With the help of Mr. Bulman, the writer has collected a large number of specimens on which observations can be based; 103 of the better-preserved complete specimens have been measured, and they show lengths varying from 0.24 mm. in the earliest or Protaspid Period to as much as 4.91 mm. in the latest or Holaspid Period.

These and the intermediate stages of growth are described in detail and certain of the aspects of this growth are discussed.

It is shown that the thoracic segments are released one by one from dorsal fusion in the posterior shield or 'transitory pygidium'; of the origin of these segments it is considered that *Shumardia pusilla* offers new evidence for the truth of the hypothesis put forward by Beecher in 1896, that the growing point of the new segments in trilobites was in front of the most posterior or anal segment. This proof was made possible by the presence in *S. pusilla* of a segment easily distinguishable from other post-cephalic segments by the possession of long pleural spines; these long spines are first definitely recognized in Degree 2, occurring as part of that segment immediately in front of the most posterior segment, and the forward movement of the spined segment is seen in later stages of the development, as segments are introduced behind it.

From the results of these observations on the movements of segments a solution is offered to the problem recently revived by Raymond concerning the true orientation of the trilobite *Agnostus*.

My thanks are primarily due to my colleague in work on the Shineton Shales, Mr. O. M. B. Bulman, who has given me most invaluable help throughout the preparation of this paper; he has collected material, drawn the reconstructions, and has been ever ready with suggestions and assistance during the preparation of the manuscript and photographs.

To Dr. W. T. Calman I would express my gratitude for encouragement and helpful advice during the earlier stages of the work, and to my old teachers, Professors W. W. Watts and A. Morley Davies, and Dr. H. G. Cannon, I am extremely grateful for their great encouragement and help in my search for literature and for kindly reading my manuscript.

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## EXPLANATION OF THE PLATES.

## PLATE 14.

Reconstructions of *Shumardia pusilla* (Sars) (figures 2-8 of the Meraspid Period).

- Fig. 1. Protaspis drawn from Specimen 81.  $\times 40$ .
- Fig. 2. Degree 0. Average individual based on Specimen 230, with information from Specimens 56 and 400.  $\times 40$ .
- Fig. 3. Degree 1. Late stage, based on Specimens 400 *a* and 401.  $\times 30$ .
- Fig. 4. Degree 2. Fairly late stage, based on Specimen 109 *a*, with information from Specimens 811, 109, and 262.  $\times 30$ .
- Fig. 5. Degree 3. Fairly early stage, based on Specimen 28, with information from Specimens 209, 31, 774, 774 *a*.  $\times 30$ .
- Fig. 6. Degree 4. Fairly late stage, based on Specimen 21, with information from Specimens 29, 205, and 171.  $\times 30$ .
- Fig. 7. Degree 5. Fairly early stage, based on Specimen 13, with information from Specimen 341.  $\times 30$ .
- Fig. 8. Degree 6. Average individual based on Specimen 26, with information from Specimens 219, 69, and 20.  $\times 30$ .
- Fig. 9. Holaspid Period. Average-sized adult based on Specimens 76 and 77, with information from Specimen 118.  $\times 20$ .

## PLATE 15.

Untouched photographs of Internal Casts of *S. pusilla* (Sars), figs. 10-15 and figs. 17-19; also of an unnamed ? variety, fig. 16.

- Fig. 10. Protaspis, Specimen 81.  $\times 30$ .
- Fig. 11. Degree 0, " 56 (average size).  $\times 30$ .
- Fig. 12. " 1, " 401 (late stage).  $\times 25$ .
- Fig. 13. " 2, " 109 *a* (fairly late stage).  $\times 25$ .
- Fig. 14. " 3, " 31 ( " " ).  $\times 25$ .
- Fig. 15. " 4, " 21 (late stage with a 4-segment pygidium).  $\times 25$ .

- Fig. 16. Anomalous *Shumardia*, Specimen 51, belonging to Degree 4 (Meraspid Period), possibly a variety of *S. pusilla* (see pp. 357 & 358). The fossil is partly preserved in pyrite, partly in shale; it shows long spinose second, third, and fourth pleuræ on the right-hand side, also traces of a genal spine.  $\times 25$ .
- Fig. 17. Degree 5, Specimen 13 (fairly early stage with a 4-segment pygidium).  $\times 25$ .
- Fig. 18. Degree 5, Specimen 60. Abnormal individual. The fourth pleural spine on the left-hand side is preserved in pyrite and the third pleural spine on the right-hand side is partly preserved as a mould. Pygidium of 5 segments.  $\times 25$ .
- Fig. 19. Degree 6 (Meraspid Period), Specimen 219. A fairly early stage.  $\times 25$ .

#### PLATE 16.

- Fig. 20. Holaspid Period, Specimen 70. Internal cast of average-sized adult.  $\times 25$ .
- Fig. 21. Holaspid Period, Specimen 118. External mould of a larger individual, showing a cephalon, compressed anteriorly, and a well-ornamented thorax and pygidium.  $\times 25$ .

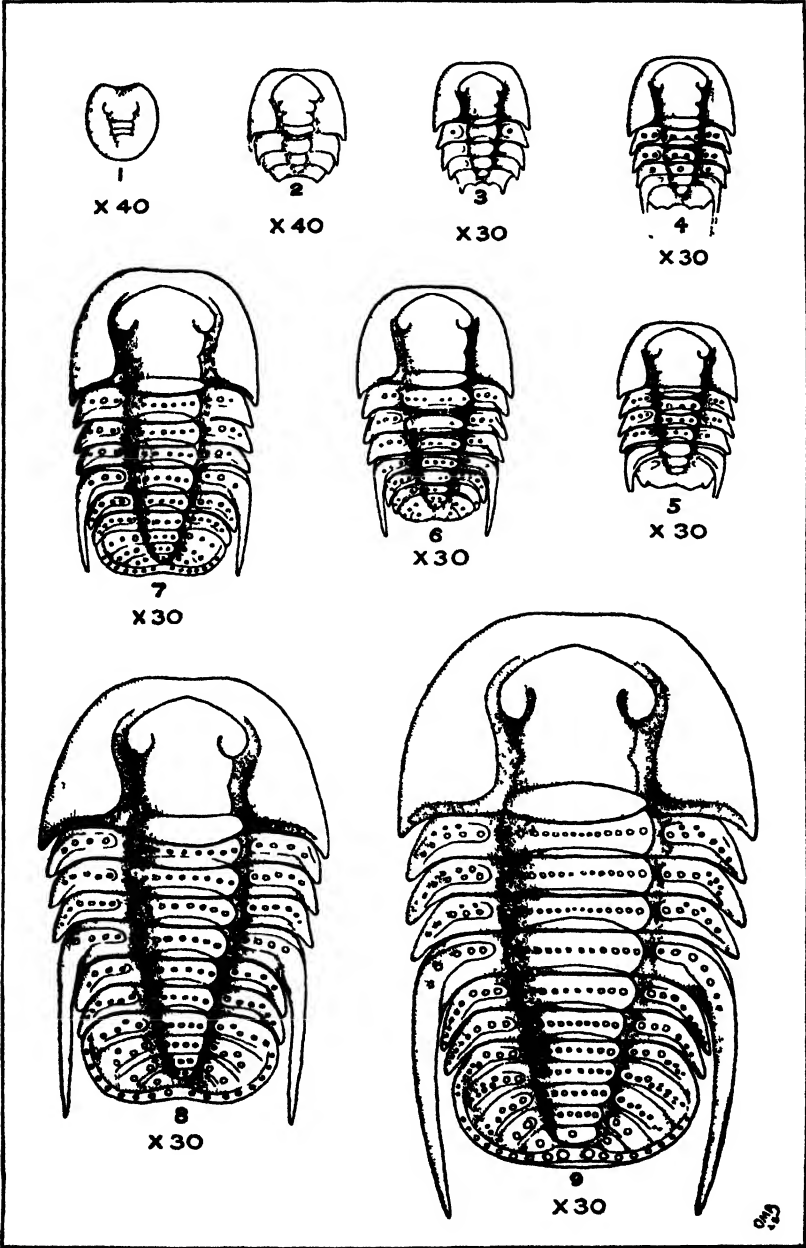
All specimens photographed here are now in the collection of the  
British Museum (Natural History).

#### Postscript.

Since reading the above, the following references have come to my notice:—

- JÆKEL, O. 1901. Beiträge zur Beurtheilung der Trilobiten. Zeitschr. d. D. geol. Ges. Bd. 53.
- RICHTER, R. 1912. Die Gattung *Dechenella* und einige verwandte Formen. Abh. d. Senckenb. Naturforsch. Ges. Bd. xxxi.
- 1925. Von Bau und Leben der Trilobiten. V. Die segmentbildung der Trilobiten. . . . Centralblatt f. Min. etc., Abt. B, No. 4, pp. 104-122.
- TROEDSSON, G. T. 1924. Remarks on the Ontogeny of *Illænus*. Geol. Fören. i Stockholm Förh. Mars-April, pp. 215-224.

Apparently both Jækel and Richter believe that the post-cephalic segment formative zone lies between the 'pygidium' and the thorax, segments being propagated backwards and forwards; Troedsson tended towards accepting this view in 1918, but has conformed to the Beecher hypothesis of 1896 since making observations on a series of isolated pygidia of *Illænus hisingeri* (var. ?) collected from the *Staurocephalus* Shale of Sweden.



SHUMARDIA PUSILLA (Sars)





10 x 36.



11 x 30.



12 x 25.



13 x 25.



14 x 25.



15 x 25.



16 x 25.



17 x 25.

Ruth coll

SHUMARDIA PUSILLA, (SARS)

C.J.S phot





Huth coll.

21 x 25.



20 x 25.

C.J.S. phot

SHUMARDIA PUSILLA, (SARS).





Tertiary Foraminifera of Victoria, Australia.—The Balcombian Deposits of Port Phillip. Part II. By FREDERICK CHAPMAN, A.L.S., F.R.M.S., and WALTER JAMES PARR.

(PLATES 17–21.)

[Read 4th November, 1926.]

THE present instalment of a description of the Balcombian Foraminifera of Port Phillip is a continuation of Part I., written by F. Chapman and published in this Journal in 1907. It has not hitherto been possible to proceed with Part II., but it is now hoped that, by collaboration, the description of the Balcombian foraminifera will be completed shortly, and that the other rich foraminiferal deposits of Victoria will then receive consideration. This work will be facilitated since the sorting and provisional naming of a very large collection from practically all the known deposits of Victoria have already been carried out.

So long a time has elapsed since Part I. was written that obviously there will be a few corrections to be made regarding the specific determinations given in that part of the work. Any additions or corrections that we may find necessary to make will be reserved for an addendum to this series.

The present part comprises the whole of the Lagenidæ and deals with eighty-six species and varieties, of which one species and one variety are described as new. Many of the already known forms have not previously been recorded from this area, as will be seen by reference to the distribution notes on each species.

### Description of the Species.

#### Family LAGENIDÆ.

#### Subfamily LAGENINÆ.

#### Genus LAGENA Walker & Boys.

#### LAGENA LÆVIS (Montagu). (Pl. 17. fig. 1.)

*Fermiculum lævis* Montagu, 1803, p. 524

*Lagena lævis* (Mont.), Brady, 1884, p. 455, pl. lvi. figs. 7–14, 30.

*Remarks.*—Brady states that this is perhaps the commonest and most widely distributed of all the *Lagenæ*. It makes its earliest appearance in rocks of Upper Silurian age, and occurs in marine deposits of almost every period to the present day. It is one of the species recorded by Watts as occurring in the “Eocene” of Mt. Martha (Balcombe Bay).

*Occurrence.*—Altona Bay Coal Shaft; very rare.

**LAGENA ELONGATA** (*Ehrenberg*). (Pl. 17. fig. 2.)*Miliola elongata* Ehrenberg, 1844, p. 274; 1854, pl. xxv. fig. 1.*Lagena elongata* (Ehr.), Brady, 1884, p. 457, pl. lvi. fig. 29.

*Remarks.*—The geological range of this species is from the Lias to the present day. Brady records it from the North Atlantic and South Pacific Oceans. It has not hitherto been recorded from the Australian Tertiaries.

*Occurrence.*—Grice's Creek; very rare.

**LAGENA DISTOMA** *Parker & Jones*. (Pl. 17. fig. 3.)

*Lagena distoma* Parker & Jones in H. B. Brady, 1884, p. 467, pl. xlviii. fig. 6; Brady, 1884, p. 461, pl. lviii. figs. 11–15; Cushman, 1923, p. 14, pl. iii. figs. 2, 3.

*Remarks.*—Seguenza recorded this species from the Pliocene of Calabria. It is usually found at the present day in shallow water of temperate latitudes. It is a common form round the British Isles.

*Occurrence.*—Altona Bay Coal Shaft; very rare.

**LAGENA GRACILIS** *Williamson*. (Pl. 17. fig. 4.)

*Lagena gracilis* Williamson, 1848, p. 13, pl. i. figs. 3, 4; Brady, 1884, p. 464, pl. lviii. figs. 19, 22–24; Cushman, 1913, p. 24, pl. viii. figs. 5, 6.

*Remarks.*—The present specimen is an extreme ovate form of the species. As a fossil *L. gracilis* has been recorded by Chapman from the Mallee Bores (Miocene or L. Pliocene); and Heron-Allen and Earland obtained it from Batesford (Miocene).

*L. gracilis* has been dredged by the F.I.S. 'Endeavour' from a station E. of Tasmania, 1122 fathoms (F. C.).

*Occurrence.*—Grice's Creek; very rare.

**LAGENA SEMISTRIATA** *Williamson*. (Pl. 17. fig. 19.)

*Lagena striata* (d'Orbigny), var. *semistriata* Williamson, 1848, p. 14, pl. i. figs. 9, 10.

*Lagena semistriata* Williamson, Brady, 1884, p. 465, pl. lvii. figs. 14, 16, 17; Heron-Allen & Earland, 1924, p. 149, pl. ix. figs. 37, 38.

*Remarks.*—This species is most common round the British Isles, but has also been recorded from the Malay Archipelago (Millett), and elsewhere. In the fossil condition it is found in the limestone of the Filter Quarries, Batesford. It is by the kindness of Mr. Arthur Collins of Melbourne, who has permitted us to make use of his collection of microzoa, that we are able to record this species.

*Occurrence.*—Altona Bay Coal Shaft; very rare.

**LAGENA STRIATA** (*d'Orbigny*). (Pl. 17. fig. 5.)

*Oolina striata* d'Orbigny, 1839, p. 21, pl. v. fig. 12.

*Lagena striata* (d'Orb.), Egger, 1893, p. 327, pl. x. figs. 21–23; Cushman, 1913, p. 19, pl. vii. figs. 4, 5.

*Remarks.*—The figured specimen is a beautifully preserved example with

numerous, delicate costæ. The earliest record of this species as a fossil appears to be from the London Clay (Eocene).

In the living condition it was found in the 'Endeavour' dredgings, E. of Tasmania, 777 fathoms, and S. of Cape Wiles, South Australia, 100 fathoms.

*Occurrence*.—Grice's Creek; very rare.

**LAGENA SULCATA** (W. & J.). (Pl. 17. fig. 6.)

*Serpula* (*Lagena*) *sulcata* Walker & Jacob, 1798, p. 634, pl. xiv. fig. 5.

*Lagena sulcata* (W. & J.), Sidebottom, 1912, p. 389, pl. xv. figs. 24, 25; Cushman, 1913, p. 22, pl. ix. fig. 2.

*Remarks*.—The tests of the present series are thin-shelled and the costæ delicate but prominent; there are annular plates on the necks of a few examples. Howchin records this species from Muddy Creek, Lower Beds (Balcombian), rare; Upper Beds (Kalimnan), very rare. It was also found by Watts at Balcombe Bay.

It occurred in the 'Endeavour' soundings S. of Cape Wiles, South Australia, at 100 fathoms (F. C.).

*Occurrence*.—Grice's Creek; common: Balcombe Bay; very rare.

**LAGENA SULCATA** (W. & J.), var. *INTERRUPTA* Williamson. (Pl. 17. fig. 7.)

*Lagena striata* (W. & J.), var. *interrupta* Williamson, 1848, p. 14, pl. i. fig. 7; Brady, 1884, p. 463, pl. lvii. figs. 25, 27; pl. lviii. figs. 5, 6.

*Remarks*.—This variety of *L. sulcata* has not hitherto been noted from our Tertiaries. It differs from the typical form in having the costæ of varying length.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

**LAGENA PLUMIGERA** Brady. (Pl. 17. fig. 8.)

*Lagena plumigera* Brady, 1884, p. 465, pl. lviii. figs. 25, 27.

*Remarks*.—In the Port Phillip area *L. plumigera* is confined to the marls occurring in the Altona Bay Coal Shaft, but we have found it in beds of similar age at Muddy Creek. It is a deep water form in the living state (1070–2425 fathoms). Brady recorded it from the tropical regions of the Pacific and off Cape Verde, and it has lately been found in dredgings made by the 'Terra Nova' in the Antarctic.

*Occurrence*.—Altona Bay Coal Shaft; frequent.

**LAGENA HISPIDA** Reuss. (Pl. 17. fig. 9.)

*Lagena hispida* Reuss, 1863, p. 335, pl. vi. figs. 77–79; Brady, 1884, p. 459, pl. lvii. figs. 1–4; Cushman, 1923, p. 26, pl. iv. figs. 7, 8.

*Remarks*.—Its earliest fossil occurrences are from the Gault of Folkestone (F. C.) and from the Chalk of Gingin, Western Australia (Howchin).

As a recent species it has been obtained from Great Barrier Island, N.Z. (F. C.), amongst numerous other localities.

*Occurrence*.—Kackeraboite Creek; very rare: Balcombe Bay; very rare.

*LAGENA FAVOSO-PUNCTATA* Brady. (Pl. 17. fig. 10.)

*Lagena favoso-punctata* Brady, 1884, p. 478, pl. lviii. fig. 35; Chapman, 1910, p. 276.

*Remarks.*—This species was previously known as a fossil from the Miocene of Batesford (F. Chapman and Heron-Allen and Earland); the present, therefore, constitutes the oldest record. It is much more abundant in the Victorian Miocene. The recent records are from Torres Straits and the N. coast of New Guinea.

An example found at Grice's Creek is an exceptionally elongated specimen.

*Occurrence.*—Grice's Creek; very rare: Altona Bay Coal Shaft; frequent: Kackeraboite Creek; very rare.

*LAGENA ANNEOTENS* Burrows & Holland. (Pl. 17. fig. 11.)

*Lagena unnectens* Burrows & Holland, in Jones, 1895, p. 203, pl. vii. fig. 11; Heron-Allen & Earland, 1924, p. 151.

*Remarks.*—This species was originally described from the Pliocene of East Anglia, and it has also been recorded from the German Oligocene and the Miocene of Batesford, Victoria.

It occurs in the living condition off the British Isles, Kerguelen Island, and the coast of New South Wales.

*Occurrence.*—Altona Bay Coal Shaft; very rare.

*LAGENA MARGINATA* (W. & B.). (Pl. 17. fig. 12.)

*Serpula (Lagena) marginata* Walker & Boys, 1784, p. 2, pl. i. fig. 7.

*Lagena marginata* (W. & B.), Brady, 1884, p. 470, pl. lix. figs. 21-23; Cushman, 1913, p. 37, pl. xxii. figs. 1-7.

*Remarks.*—The majority of the shells found show a thickened keel, the thin flanged tests being referred to the variety *catenulosa*. A form with the margin denticulated aborally also occurs, but is not figured.

The geological range of this species is from the Cretaceous to the present day. It has been recorded by Howchin from the Lower Beds (Oligocene) of Muddy Creek, and by Heron-Allen and Earland from the Miocene of Batesford.

In the recent condition *L. marginata* is found in every ocean and at every depth.

*Occurrence.*—Grice's Creek; very rare: Balcombe Bay; rare: Kackeraboite Creek; common.

*LAGENA MARGINATA* (W. & B.), var. *CATENULOSA* Chapman. (Pl. 17. fig. 13.)

*Lagena marginata* (Walker & Boys), var. *catenulosa* Chapman, 1895, p. 28, pl. i. fig. 5; Sidebottom, 1912, p. 407, pl. xviii. fig. 6.

*Remarks.*—This variety was first described from recent specimens dredged in the Arabian Sea. Sidebottom obtained it from dredgings off the coast of New South Wales.

*Occurrence.*—Grice's Creek; very rare: Altona Bay Coal Shaft; rare,

**LAGENA MARGINATO-PERFORATA** *Seguenza*. (Pl. 17. fig. 14.)

*Lagena marginato-perforata* Seguenza, 1880, p. 332, pl. xvii. fig. 34; Sidebottom, 1913, p. 189, pl. xvi. figs. 23-25.

*Remarks*.—Seguenza's specimens of this species came from the later Tertiary deposits of Southern Italy, and it has been recorded by Halkyard from the Eocene of Biarritz. Sidebottom found it to be a very common form in dredgings made off the coast of New South Wales at depths ranging from 328 to 2712 fathoms.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

**LAGENA SCHLICHTI** (*A. Silvestri*). (Pl. 17. fig. 15.)

*Fissurina schlichti* A. Silvestri, 1902, p. 14, woodcuts, figs. 9-11.

*Lagena schlichti* (A. Silv.), Chapman, 1909, p. 337, pl. xv. figs. 7*a*, *b*; *Ibid.*, 1910, p. 66, pl. iv. fig. 27.

*Remarks*.—This species is easily confused with *L. marginata*, from which it differs in having the aperture eccentrically situated. The long entosolenian tube is well shown in our example. It occurs in the Mallee Bores (Miocene and L. Pliocene), and in the recent condition in the seas around New Zealand.

*Occurrence*.—Grice's Creek; very rare.

**LAGENA QUADRATA** (*Williamson*). (Pl. 17. fig. 16.)

*Entosolenia marginata* Montagu, var. *quadrata* Williamson, 1858, p. 11, pl. i. figs. 27, 28.

*Lagena quadrata* (Williamson), Brady, 1884, p. 475, pl. lix. figs. 3, 16; Bagg, 1912, p. 50, pl. xiv. figs. 19*a*, *b*, 20.

*Remarks*.—A single minute specimen of this form has been found in the marl of the Altona Bay Coal Shaft. It has not previously been recorded from beds of greater age than the Miocene, in deposits of which age it occurs in Southern Italy. *L. quadrata* is widely distributed in modern seas, and is usually found in water not deeper than 150 fathoms. It has been recorded by one of us (F. C.) from off the Snares, S. of New Zealand, at 60 fathoms.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

**LAGENA ORBIGNYANA** (*Seguenza*). (Pl. 17. fig. 17.)

*Fissurina orbignyana* Seguenza, 1862, p. 66, pl. ii. figs. 25, 26.

*Lagena orbignyana* (Seg.), Flint, 1899, p. 308, pl. liv. fig. 4; Chapman, 1909, p. 337 pl. xv. fig. 10.

*Remarks*.—In addition to the typical form, a specimen was found in the clays of the Altona Bay Coal Shaft of a sub-quadrate type, almost like Williamson's *L. quadrata*, but the affinity is otherwise with *L. orbignyana*.

*L. orbignyana* has previously occurred in the Miocene of Batesford (Heron-Allen and Earland). Terquem obtained it in deposits as old as the Eocene of the Paris Basin, and Gumbel from a similar formation in the Bavarian Alps. It has occurred in younger deposits to the present time. As a living species

it has been recorded from around the Sub-antarctic Islands of New Zealand and in the Ross Sea.

*Occurrence*.—Grice's Creek; very rare: Balcombe Bay; common: Altona Bay Coal Shaft; very rare: Kackeraboite Creek; very rare.

**LAGENA LACUNATA** *Burrows & Holland.* (Pl. 17. fig. 18.)

*Lagena lacunata* Burrows & Holland, in Jones, 1895, p. 205, pl. vii. figs. 12 a, b.

*Remarks*.—This species was described from Pliocene (Crag) deposits by Burrows and Holland. As a living form it was recorded by Dr. Brady under the name of *L. castrensis* Schwager from, amongst other places, off East Moncoeur Island, Bass Strait, at 38 fathoms. It also occurred in dredgings made by the 'Endeavour' off the east coast of Tasmania at 777 fathoms.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

#### Subfamily NODOSARIINÆ.

#### Genus NODOSARIA *Lamarck.*

#### Subgenus GLANDULINA *d'Orbigny.*

**NODOSARIA (GLANDULINA) LÆVIGATA** *d'Orbigny.* (Pl. 17. fig. 20.)

*Nodosaria (Glandulina) lævigata* d'Orbigny, 1826, p. 252, pl. x. figs. 1-3; Brady, 1884, p. 490, pl. lxi. figs. 17-22, 32; Chapman, 1916, p. 31, pl. iii. fig. 19.

*Remarks*.—The specimens now under notice vary considerably in build, some being shorter and stouter than the type, while others are longer and narrower. The geological range of this species is from the Upper Trias to the present day. It has been recorded from the Lower Beds (Oligocene) of Muddy Creek, and also occurs in the Batesford limestone (Miocene). As a recent species it is of almost cosmopolitan distribution.

*Occurrence*.—Grice's Creek; rare: Kackeraboite Creek; rare.

**NODOSARIA SCALARIS** (*Batsch*). (Pl. 17. fig. 21.)

*Nautilus (Orthoceras) scalaris* Batsch, 1791, No. 4, pl. ii. figs. 4 a, b.

*Nodosaria scalaris* (Batsch), Brady, 1884, p. 510, pl. lxiii. figs. 28-31; Howchin, 1889, p. 9.

*Remarks*.—This species is of frequent occurrence in the Victorian and other Tertiary deposits. It was recorded by Watts under the name of *N. longicauda* from Mt. Martha (Balcombe Bay). In the recent condition it has been found by one of us (F. C.) in shore sand at Beaumaris, Victoria, and it is elsewhere widely distributed.

*Occurrence*.—Grice's Creek; very common: Balcombe Bay; common: Altona Bay Coal Shaft; rare: Kackeraboite Creek; very rare.

**NODOSARIA SCALARIS** (*Batsch*), var. *SEPARANS* *Brady*. (Pl. 18. fig. 22.)

*Nodosaria scalaris* (Batsch), var. *separans*, Brady, 1884, p. 510, pl. lxiv. figs. 16-19.

*Remarks*.—This variety of *N. scalaris* is of very rare occurrence in the Victorian Balcombian deposits. It now occurs frequently in Southern Australian and New Zealand Seas at depths ranging from 100-275 fathoms.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

**NODOSARIA LONGISCATA** *d'Orbigny*. (Pl. 18. fig. 23.)

*Nodosaria longiscata* d'Orbigny, 1846, p. 32, pl. i. figs. 10-12.

*Nodosaria arundinea* Schwager, 1866, p. 211, pl. v. figs. 43-45.

*Nodosaria longiscata* d'Orb., Brady, 1888, p. 5; Sherborn & Chapman, 1889, p. 486, pl. xi. figs. 17-18.

*Remarks*.—Only fragments of this very fragile species have been found. Its oldest record appears to be that of Burrows, Sherborn and Bailey from the Red Chalk of Speeton, Yorkshire\*. It is well distributed through Tertiary deposits, occurring in the Eocene of London and Biarritz; the Miocene of the Vienna Basin; near Malaga, Spain; and Barbados. Schwager's specimens came from the Pliocene deposits of Kar Nicobar, while Brady recorded it from the Post-Tertiary "Soapstone" of Fiji and the Solomon Islands. No record can be found of the occurrence of *N. longiscata* in the living condition.

*Occurrence*.—Grice's Creek; rare: Balcombe Bay; rare: Kackeraboite Creek; rare: Altona Bay Coal Shaft; rare.

**NODOSARIA OVICULA** *d'Orbigny*. (Pl. 18. fig. 24.)

*Nodosaria ovicula* d'Orbigny, 1826, No. 6; Parker, Jones & Brady [Soldani], 1871, p. 164, pl. ix. fig. 36.

*Remarks*.—The oldest record of *N. ovicula* appears to be that of Prof. Rupert Jones from the English Chalk†. Soldani found it in the Pliocene deposits of Siena. All of our specimens are fragmentary.

*Occurrence*.—Kackeraboite Creek; rare: Grice's Creek; very rare.

**NODOSARIA HISPIDA** *d'Orbigny*. (Pl. 18. fig. 25.)

*Nodosaria hispida* d'Orbigny, 1846, p. 35, pl. i. figs. 24, 25; Brady, 1884, p. 507, pl. lxiii. figs. 12-16.

*Remarks*.—*N. hispida* is yet another of the foraminifera described by d'Orbigny from the Miocene of the Vienna Basin, occurring in the Victorian Balcombian deposits. Its geological range is from the Lias of the West of England to the present day. The 'Challenger' records were from the Atlantic and Pacific Oceans at depths ranging from 95 to 450 fathoms.

*Occurrence*.—Grice's Creek; very rare.

\* Burrows, Sherborn & Bailey, 1890, p. 556, pl. ix. fig. 20.

† Jones, T. R., 1882, p. 87.

**NODOSARIA FISTUCA** Schwager. (Pl. 18. fig. 26.)

*Nodosaria fistuca* Schwager, 1866, p. 216, pl. v. figs. 36, 37; Fornasini, 1900, p. 378, woodcut, fig. 27 in text.

*Remarks.*—*N. fistuca* has once been recorded, from the Italian Tertiaries, since Schwager described it from the Pliocene of Kar-Nicobar. It is a short stoutly built form, with chambers rapidly increasing in size, and the surface aculeate or hispid. The specimen found is fragmentary, but it resembles Schwager's figure 36 very closely.

*Occurrence.*—Balcombe Bay; very rare.

**NODOSARIA RAPHANUS** (Linné). (Pl. 18. fig. 27.)

*Nautilus raphanus* Linné, 1767, p. 1164, No. 283.

*Nodosaria raphanus* (Linné), Brady, 1884, p. 512, pl. lxiv. figs. 6-10; Chapman, 1907, p. 129.

*Remarks.*—This is found in foraminiferal deposits from the Trias to the present day. In Australia it has occurred in the Oligocene of Muddy Creek (Howchin), and the Lower Pliocene of the Mallee Bores (Chapman). One of us (F. C.) has recorded it from shore sand at Beaumaris, Victoria.

*Occurrence.*—Grice's Creek; frequent.

**NODOSARIA VERTEBRALIS** (Batsch). (Pl. 18. fig. 28.)

*Nautilus (Orthoceras) vertebralis* Batsch, 1791, p. 3, No. 6, pl. ii. fig. 6 a, b.

*Nodosaria vertebralis* (Batsch), Brady, 1884, p. 514, pl. lxiii. fig. 35, pl. lxiv. figs. 11-14; Heron-Allen & Earland, 1924, p. 155.

*Remarks.*—This well-known species has been recorded from the Gingen Chalk of Western Australia (Howchin) and the Miocene of Batesford. It is fairly widely distributed in the recent condition, Australian records being from dredgings off Great Barrier Island and Enderby Island, and in shore sand from Sorrento, Victoria (F. C.).

A specimen found at Altona Bay Coal Shaft is a dentaline form of the species.

*Occurrence.*—Grice's Creek; very rare: Balcombe Bay; very rare: Altona Bay Coal Shaft; very rare.

**NODOSARIA RAPHANISTRUM** (Linné). (Pl. 18. fig. 29.)

*Nautilus raphanistrum* Linné, 1767, p. 1163; 1788, p. 3372.

*Nodosaria raphanistrum* (Linné), Jones, Parker & Brady, 1866, p. 50, pl. i. figs. 6-8; Sherborn & Chapman, 1886, p. 749, pl. xiv. fig. 38.

*Remarks.*—*N. raphanistrum* is of somewhat rare occurrence in the Australian Tertiaries, but the specimens found are usually well developed and typical. It has a wide range as a fossil, its oldest recorded occurrence according to Jones, Parker and Brady being from the Upper Trias. It is, however, commonest in Tertiary strata, having been found in the European,



American, and Australian Tertiaries. In the living condition, this species has been recorded from the Mediterranean Sea.

*Occurrence*.—Grice's Creek ; very rare : Kackeraboite Creek ; very rare : Altona Bay Coal Shaft ; very rare.

*NODOSARIA BADENENSIS d'Orbigny.* (Pl. 18. fig. 30.)

*Nodosaria badensis* d'Orbigny, 1846, p. 38, pl. i. figs. 34, 35 ; Chapman, 1910, p. 278.

*Remarks*.—This species is typical of the Vienna Basin fauna, and the Australian examples are quite comparable in size with the original specimens. It is well-distributed through the Victorian Tertiary strata, and has been recorded from the limestone of the Filter Quarries, Batesford (Miocene) and the Mallee Bores (F. C.).

*Occurrence*.—Grice's Creek ; very rare : Kackeraboite Creek ; very rare.

Subgenus *DENTALINA d'Orbigny.*

*NODOSARIA (DENTALINA) COMMUNIS (d'Orbigny).* (Pl. 18. fig. 31.)

*Dentalina communis* d'Orbigny, 1826, p. 254, No. 35.

*Nodosaria (Dentalina) communis* (d'Orb.), Brady, 1884, p. 504, pl. lxii. figs. 19-22 ; Chapman, 1917, p. 18, pl. iii. fig. 32.

*Remarks*.—A species of world-wide distribution. In Australia it has occurred in the Chalk of Gingin, Western Australia (F. C.), and the Filter Quarries, Batesford.

*Occurrence*.—Grice's Creek ; very rare : Altona Bay Coal Shaft ; rare : Kackeraboite Creek ; very rare.

*NODOSARIA (DENTALINA) ELEGANTISSIMA (d'Orbigny).* (Pl. 18. fig. 32.)

*Dentalina elegantissima* d'Orbigny, 1846, p. 55, pl. ii. figs. 33-35.

*Remarks*.—This species was described from beds of Miocene age near Vienna. It does not appear to have been recorded in the living condition.

*Occurrence*.—Altona Bay Coal Shaft ; very rare.

*NODOSARIA (DENTALINA) CONSOBRINA (d'Orbigny).* (Pl. 18. fig. 33.)

*Dentalina consobrina* d'Orbigny, 1846, p. 46, pl. ii. figs. 1-3.

*Nodosaria (Dentalina) consobrina* (d'Orb.), Brady, 1884, p. 501, pl. lxii. figs. 23, 24 ; Chapman, 1909, p. 341.

*Remarks*.—Another widely distributed species. It has been recorded from the Irish Chalk and the European Tertiaries, and is found through the whole range of the Victorian Tertiary deposits. As a recent form, it has occurred in dredgings off Great Barrier Island, New Zealand (F. C.).

*Occurrence*.—Kackeraboite Creek ; rare.

**NODOSARIA (DENTALINA) CONSOBRINA** (*d'Orbigny*), var. **EMACIATA** *Reuss*. (Pl. 18. fig. 34.)

*Dentalina emaciata* Reuss, 1851, p. 63, pl. iii. fig. 9.

*Nodosaria (Dentalina) consobrina* (*d'Orb.*), var. *emaciata* Reuss, Brady, 1884, p. 502, pl. lxii. figs. 25, 26; Chapman, 1917, p. 18, pl. iii. fig. 33.

**Remarks.**—The earliest record of this variety of *N. (D.) consobrina* in Australia is from the Chalk of Gingin, W.A. It has a distribution similar to that of the specific form.

**Occurrence.**—Kackeraboite Creek; very rare.

**NODOSARIA (DENTALINA) BOUEANA** (*d'Orbigny*). (Pl. 19. fig. 35.)

*Dentalina boueana* *d'Orbigny*, 1846, p. 47, pl. i. figs. 4-6.

**Remarks.**—This species is a form intermediate between *N. (D.) consobrina* and *N. ovicula*. It has been found in beds of Miocene age in the Vienna Basin, and in Barbados, and was recorded by Goëss as a living species from the Caribbean Sea.

**Occurrence.**—Grice's Creek; rare.

**NODOSARIA (DENTALINA) LORNEIANA** (*d'Orbigny*). (Pl. 19. fig. 36.)

*Dentalina lorneiana* *d'Orbigny*, 1840, p. 14, pl. i. figs. 8, 9.

*Nodosaria lorneiana* (*d'Orb.*), Reuss, 1845 (1846), pt. i. p. 27, pl. viii. fig. 5.

*Nodosaria (Dentalina) lorneiana* (*d'Orb.*), Chapman, 1917, p. 19, pl. iv. fig. 34.

**Remarks.**—This typically Cretaceous form has been recorded from the Gault and Chalk of England, the Chalk of France, Bavaria, Bohemia, and Northern Ireland, and in the Gingin Chalk of Western Australia. This constitutes its first record from beds of later date.

**Occurrence.**—Grice's Creek; very rare

**NODOSARIA (DENTALINA) FARCIMEN** (*Soldani*). (Pl. 19. fig. 37.)

"*Orthoceras farcimen*" *Soldani*, 1791, pl. cv. fig. O.

*Dentalina farcimen* Reuss, 1863, p. 146, pl. i. fig. 18.

*Nodosaria (Dentalina) farcimen* (Reuss), Brady, 1884, p. 498, pl. lxii. figs. 17, 18

**Remarks.**—A species of world-wide distribution. As a fossil its oldest recorded occurrence is that of Howchin from the Carboniferous of the North of England\*. It was found by Heron-Allen and Earland in the Miocene of Batesford, Victoria.

**Occurrence.**—Grice's Creek; rare: Balcombe Bay; very rare.

**NODOSARIA (DENTALINA) PAUPERATA** (*d'Orbigny*). (Pl. 19. fig. 38.)

*Dentalina pauperata* *d'Orbigny*, 1846, p. 46, pl. i. figs. 57, 58.

*Nodosaria (Dentalina) pauperata* (*d'Orb.*), Brady, 1884, p. 500, fig. 14 (in text); Chapman, 1910, p. 277.

**Remarks.**—Distribution similar to that of *N. (D.) communis*. It has been recorded from both Lower and Upper Beds at Muddy Creek by Howchin and is also of fairly frequent occurrence at Batesford.

\* Howchin, 1888, p. 11, pl. ix. figs. 21 a, b.

*Occurrence*.—Grice's Creek ; rare : Altona Bay Coal Shaft ; very rare : Kackeraboite Creek ; very rare.

**NODOSARIA (DENTALINA) ROEMERI** (*Neugeboren*). (Pl. 19. fig. 39.)

*Dentalina roemeri* Neugeboren, 1856, p. 82, pl. ii. figs. 13-17.

*Nodosaria (Dentalina) roemeri* (Neug.), Brady, 1884, p. 505, pl. lxiii. fig. 1 ; Chapman, 1909, p. 340.

*Remarks*.—The geological range of this species is from the Bargate Stone Beds of Surrey (of Aptian age) to the present day. Heron-Allen and Earland recorded it from the Miocene of Batesford. As a recent species it has been identified by one of us (F. C.) in dredgings made off Great Barrier Island, N.Z., and around the Auckland and Enderby Islands, south of New Zealand.

*Occurrence*.—Balcombe Bay ; very rare.

**NODOSARIA (DENTALINA) SOLUTA** (*Reuss*). (Pl. 19. fig. 40.)

*Dentalina soluta* Reuss, 1851, p. 60, pl. iii. fig. 4 a, b.

*Nodosaria (Dentalina) soluta* (Reuss), Brady, 1884, p. 503, pl. lxii. figs. 13-16 ; Chapman, 1917, p. 17, pl. iii. fig. 28.

*Remarks*.—This species, which occurs in foraminiferal deposits from the Cretaceous to the present day, is the commonest form of *Nodosaria* found in the Balcombian deposits of Port Phillip. In the living condition it has been recorded from the Atlantic and South Pacific Oceans at depths ranging from 125 to 1360 fathoms.

*Occurrence*.—Grice's Creek ; very common : Balcombe Bay ; frequent : Kackeraboite Creek ; common : Altona Bay Coal Shaft ; very common.

**NODOSARIA (DENTALINA) RETRORSA** (*Reuss*). (Pl. 19. fig. 41.)

*Dentalina retrorsa* Reuss, 1864, p. 46, pl. iii. fig. 27.

*Nodosaria (Dentalina) retrorsa* (Reuss), Brady, 1884, p. 507, pl. lxiii. fig. 7 ; Chapman, 1917, pl. iv. fig. 36.

*Remarks*.—This species has been noted as occurring in the Chalk of Bavaria, the Gingin Chalk of Western Australia, and the Septarian Clays (Oligocene) of Germany. Brady found it in dredgings made off the Ki Islands at 580 fathoms.

*Occurrence*.—Grice's Creek ; very rare.

**NODOSARIA (DENTALINA) PYRULA** *d'Orbigny*, var. **SEMIRUGOSA**, *d'Orb.* (Pl. 19. fig. 42.)

*Nodosaria semirugosa* d'Orbigny, 1846, p. 34, pl. i. figs. 20-23 ; Millett, 1902, p. 515, pl. xi. fig. 5.

*Nodosaria stipitata* Reuss, var. *costulata* Reuss, 1870, p. 471 (fig. von Schlicht, 1870, pl. vii. fig. 21).

*Nodosaria costulata* Reuss, Brady, 1884, p. 515, pl. lxiii. figs. 23-27.

*Nodosaria pyrula* d'Orb., var. *semirugosa* d'Orb., Cushman, 1913, p. 50, pl. xxvi. figs. 4-8.

*Remarks*.—Typical specimens of *N. pyrula* have not been met with in the

Balcombian deposits of Port Phillip, but are associated with the variety *semirugosa* in the Miocene of Batesford. *N. pyrula* and its varieties have been found in deposits as old as the Eocene and through beds of later date to the present day. In the living condition they are widely distributed, most of the records being from tropical and sub-tropical waters, although they also occur around the British Isles.

*Occurrence*.—Grice's Creek ; rare : Kackeraboite Creek ; very rare.

NODOSARIA (DENTALINA) PYRULA *d'Orbigny*, var. LONGICOSTATA *Cushman*. (Pl. 19. fig. 43.)

*Nodosaria pyrula* d'Orb., var. *longicostata* Cushman, 1917, p. 653; 1921, p. 188, pl. xxxiii. figs. 8, 9.

*Remarks*.—This variety of *N. pyrula* differs from the preceding in having the costæ running the full length of each chamber. It was found by Halkyard in beds of Eocene age at Biarritz, and recorded by him under the name of *N. semirugosa* d'Orb. Cushman found it in company with the variety *semirugosa* around the Philippines.

*Occurrence*.—Kackeraboite Creek ; very rare.

NODOSARIA (DENTALINA) SEMIPPLICATA (*d'Orbigny*). (Pl. 19. fig. 44.)

*Dentalina semiplicata* d'Orbigny, 1846, p. 52, pl. ii. figs. 24, 25.

*Remarks*.—This striking species is very rarely recorded. It was described by d'Orbigny from beds of Miocene age near Vienna.

*Occurrence*.—Altona Bay Coal Shaft ; very rare.

NODOSARIA (DENTALINA) FISSICOSTATA (*Gümbel*). (Pl. 19. fig. 45.)

*Dentalina fissicostata* Gümbel, 1870, p. 626, pl. i. fig. 46; Hantken, 1881, p. 37, pl. iii. fig. 19.

*Remarks*.—This species is a variant of *N. obliqua*, having all the chambers well inflated. It has previously been recorded from the Older Tertiaries of Bavaria and Hungary.

*Occurrence*.—Balcombe Bay ; rare : Kackeraboite Creek ; very rare ; Altona Bay Coal Shaft ; rare.

NODOSARIA (DENTALINA) OBLIQUA (*Linné*). (Pl. 19. fig. 46.)

*Nautilus obliquus* Linné, 1767, p. 1163, No. 281.

*Nodosaria obliqua* (Linné), Brady, 1884, p. 513, pl. lxiv. figs. 20–22.

*Nodosaria (Dentalina) obliqua* (Linné), Chapman, 1917, p. 20, pl. iv. fig. 39.

*Remarks*.—This species is found in all fossiliferous deposits from the Permian to the present day. It is one of the commonest species of *Nodosaria* occurring in the Victorian Tertiary Beds. In the living condition it is of world-wide distribution.

*Occurrence*.—Grice's Creek ; very common : Balcombe Bay ; frequent : Altona Bay Coal Shaft ; frequent.

**NODOSARIA (DENTALINA) MULTILINEATA** (*Bornemann*). (Pl. 19. fig. 47.)

*Dentalina multilineata* Bornemann, 1855, p. 325, pl. xiii. fig. 12; Sherborn & Chapman, 1886, p. 751, pl. xv. fig. 14.

*Remarks.*—This species appears to be known in the fossil condition only. It was described from the Oligocene of Germany, and also occurs in the London Clay (Eocene) of London, the Lower Beds (Oligocene) at Muddy Creek (Howchin), and in the strata of Miocene age in the Mallee Bores (F. C.).

*Occurrence.*—Grice's Creek; very rare.

**NODOSARIA (DENTALINA) ACUTA** (*d'Orbigny*). (Pl. 19. fig. 48.)

*Dentalina acuta* d'Orbigny, 1846, p. 56, pl. ii. figs. 40-43; Hantken, 1881, p. 36, pl. iii. fig. 20.

*Remarks.*—This is a dentaline form intermediate between *N. raphanus* and *N. vertebralis*. It has previously been recorded from the Older Tertiaries of Austria and Hungary, beds of Eocene age at Biarritz, France, and the Pliocene of Italy.

*Occurrence.*—Altona Bay Coal Shaft; very rare.

Genus **LINGULINA** *d'Orbigny*.**LINGULINA SEMINUDA** *Hantken*. (Pl. 20. fig. 49.)

*Lingulina costata* d'Orb., var. *seminuda* Hantken, 1881, p. 41, pl. iv. figs. 8 a, b.

*Lingulina carinata* d'Orb., var. *seminuda* Hantken, Brady, 1884, p. 518, pl. lxxv. figs. 14, 15.

*Lingulina seminuda* Hantken, Cushman, 1923, p. 95, pl. xvii. figs. 8, 9, 11; pl. xviii. figs. 1, 2.

*Remarks.*—Hantken described this species from the Older Tertiary (*Clavulina Szaboischichten*) of Hungary. It is of very rare occurrence in beds of Balcombian age, but we have found it to be not uncommon in the Miocene marl overlying the limestone of the Filter Quarries at Batesford, and at Shelford, both in Victoria. Recent records of the species are nearly all from the Atlantic Ocean, at depths ranging from 390-1200 fathoms, and it is commonest in warm water areas. The only Pacific record we are acquainted with is that of one of us (F.C.) from outside the reef at Funafuti, at 200 fathoms.

*Occurrence.*—Balcombe Bay; very rare.

Genus **FRONDICULARIA** *DeFrance*.**FRONDICULARIA INÆQUALIS** *Costa*. (Pl. 20. fig. 50.)

*Frondicularia inæqualis* Costa, 1857, p. 372, pl. iii. fig. 3; Brady, 1884, p. 521, pl. lxxvi. figs. 8-12; Fornasini, 1895, p. 5.

*Frondicularia advena* Cushman, 1923, p. 141, pl. xx. figs. 1, 2.

*Remarks.*—Cushman has referred the forms figured by Brady as *F. inæqualis* to a new species, *F. advena*. It has not been possible to compare

the Balcombian specimens with Costa's original figures, but the figures given in Fornasini's paper on Costa's collection (*op. supra cit.*), show a form from which *F. advena* does not appear to differ materially. *F. inæqualis* occurs in the Miocene of Batesford and the Mallee Bores, and in the recent condition is found off the Ki Islands, Raine Island, around the Philippines, off the west coast of New Zealand and elsewhere. As noted by Cushman, it is a very fragile species.

*Occurrence*.—Grice's Creek ; rare : Balcombe Bay ; very rare : Altona Bay Coal Shaft ; very rare : Kackeraboite Creek ; very rare.

*FRONDIOLARIA COMPTA* Brady. (Pl. 20. fig. 51.)

*Frondicularia compta* Brady, 1879, p. 271, pl. viii. fig. 6; *Idem*, 1884, p. 520, pl. lxxv. fig. 19; Heron-Allen & Earland, 1924, p. 156, pl. x. figs. 51-53.

*Remarks*.—It is interesting to record this species from strata of Oligocene age in Victoria. It was first described by Brady from dredgings made off East Moncoeur Island, Bass Strait, at 38 fathoms; and Heron-Allen and Earland have lately figured specimens from the Filter Quarries, Batesford (Miocene).

*Occurrence*.—Grice's Creek ; very rare.

Genus *TRIFARINA* Cushman.

*TRIFARINA BRADYI* Cushman. (Pl. 20. fig. 52.)

*Rhabdognium tricarinatum* Brady, 1884 (non *Vaginulina tricarinata* d'Orbigny, 1826), p. 525, pl. lxxvii. figs. 1-3; Egger, 1893, p. 355, pl. xi. figs. 49, 50; pl. xii. figs. 36-38.

*Triplasia tricarinata* (d'Orb.), Cushman, 1913, p. 62, pl. xxxix. fig. 2.

*Trifarina bradyi* Cushman, 1923, p. 99, pl. xxii. figs. 8-9.

*Remarks*.—This species, usually recorded under the name of *Rhabdognium tricarinatum* (d'Orb.), has been shown by Dr. Cushman (*op. cit.*) to be distinct from d'Orbigny's *Vaginulina tricarinata*, and with affinities with the genus *Uvigerina* rather than with *Rhabdognium*. He has placed it in a new genus, *Trifarina*, under the name of *T. bradyi*.

*T. bradyi* is of common occurrence in the Victorian Miocene, and in the living condition has a wide range.

*Occurrence*.—Balcombe Bay ; frequent.

Genus *VAGINULINA* d'Orbigny.

*VAGINULINA LEGUMEN* (Linné). (Pl. 20. fig. 53.)

*Nautinus legumen* Linné, 1767, p. 1164, No. 288.

*Vaginulina legumen* (Linné), Brady, 1884, p. 530, pl. lxxvi. figs. 13-15; Chapman, 1917, p. 27, pl. viii. fig. 67.

*Remarks*.—The range of this well-known form is from the Trias to the present day. Its oldest occurrence in Australia is in the Gingga (Chalk, in

which it is one of the commonest species found. In the recent condition it has a cosmopolitan distribution.

*Occurrence*.—Grice's Creek; rare: Kackeraboite Creek; rare.

#### Genus MARGINULINA d'Orbigny.

##### MARGINULINA GLABRA d'Orbigny. (Pl. 20. fig. 54.)

*Marginulina glabra* d'Orbigny, 1826, p. 259, No. 6, Modèle No. 55; Chapman, 1917, p. 27, pl. vii. fig. 65; Cushman, 1923, p. 127, pl. xxxvi. figs. 5, 6.

*Remarks*.—This species has a geological range from the Rhætic to the present day, its oldest record in Australian strata being that of one of us (F.C.) from the Chalk of Gingin, W.A.

*Occurrence*.—Balcombe Bay; very rare.

##### MARGINULINA COSTATA (Batsch). (Pl. 20. fig. 55.)

*Nautilus (Orthoceras) costatus* Batsch, 1791, p. 2, pl. i. fig. 1 a-g.

*Marginulina costata* (Batsch), Brady, 1884, p. 528, pl. lxxv. figs. 10-13.

*Remarks*.—This species is found in foraminiferal deposits from the Lias to the present day. In present day seas it is widely distributed, but is most frequently recorded from the Atlantic Ocean.

*Occurrence*.—Grice's Creek; common: Balcombe Bay; very rare: Altona Bay Coal Shaft; very rare.

#### Genus FLABELLINA d'Orbigny.

##### FLABELLINA OOLITHICA Deecke. (Pl. 20. fig. 56.)

*Flabellina oolithica* Deecke, 1884, p. 52, pl. i. figs. 23-23 b; Dervieux, 1893, p. 8, pl. iv. figs. 24-25.

*Remarks*.—The beautiful specimen figured is one of the most interesting discoveries in the Victorian Balcombian Beds. It is undoubtedly referable to Deecke's species which was described from beds of Jurassic age in Alsace. Dervieux has since recorded it from the Middle Tertiaries of Piedmont.

*Occurrence*.—Grice's Creek; very rare.

#### Genus CRISTELLARIA Lamarck.

##### CRISTELLARIA CREPIDULA (Fichtel & Moll). (Pl. 20. fig. 57.)

*Nautilus crepidula* Fichtel & Moll, 1798, p. 107, pl. xix. figs. G-I.

*Cristellaria crepidula* (F. & M.), Brady, 1884, p. 542, pl. lxxvii. figs. 17, 19, 20; Cushman, 1923, p. 117, pl. xxxv. figs. 3, 4.

*Remarks*.—As a fossil this species is found in deposits from the Lias to the present day. In the recent condition it is usually characteristic of fairly shallow water and temperate latitudes, but has been recorded by one of us (F.C.) from elevated deposits on the slopes of Mount Erebus, in the Antarctic.

*Occurrence*.—Grice's Creek; rare: Balcombe Bay; frequent: Kackeraboite Creek; very rare.

*CRISTELLARIA CREPIDULA* (F. & M.), var. *GLADIUS Philippi*. (Pl. 20. fig. 58.)

*Marginula gladius* Philippi, 1843, p. 40, pl. i. fig. 37.

*Cristellaria crepidula* (F. & M.), var. *gladius* Philippi var., Burrows & Holland, 1897, p. 40, pl. i. figs. 6, 9, 16.

*Cristellaria gladius* (Phil.), Chapman, 1917, p. 40, pl. viii. fig. 73.

*Remarks*.—In Australia this variety of *C. crepidula* occurs in the Gingin Chalk, and in the limestone of the Filter Quarries, Batesford (of Miocene age). It does not appear to have been recorded in the living condition.

*Occurrence*.—Balcombe Bay; rare.

*CRISTELLARIA PROTRACTA* Bornemann. (Pl. 20. fig. 59.)

*Cristellaria protracta* Bornemann, 1854, p. 39, pl. iv. figs. 27 a, b; Burbach (Dreyer), 1888, p. 409, pl. x. figs. 4-9; Crick & Sherborn, 1892, p. 71, pl. ii. fig. 2'; Burrows & Holland, 1897, pp. 40, 50, pl. i. figs. 8, 13-15.

*Remarks*.—This is an elongated variant of the *C. crepidula* type; hitherto recorded from the Lias formation, and the Thanet Sand (Lower Eocene).

*Occurrence*.—Balcombe Bay; very rare: Kackeraboite Creek; rare: Altona Bay Coal Shaft; very rare.

*CRISTELLARIA ELONGATA* d'Orbigny. (Pl. 20. fig. 60.)

*Cristellaria elongata* d'Orbigny, 1826, p. 292, No. 11; Fornasini, 1883, p. 187, pl. ii. figs. 8 a, b; Heron-Allen & Earland, 1924, p. 159.

*Remarks*.—This handsome species is another of the *C. crepidula* group, in which the earlier portion of the test is keeled. It is also found in the Batesford limestone (Miocene).

*Occurrence*.—Altona Bay Coal Shaft; very rare.

*CRISTELLARIA GIBBA* d'Orbigny. (Pl. 20. fig. 61.)

*Cristellaria gibba* d'Orbigny, 1826, p. 292, No. 17; *Id.*, 1839, p. 40, pl. vii. figs. 20, 21; Chapman, 1917, p. 31, pl. ix. fig. 82; Cushman, 1923, p. 105, pl. xxv. fig. 4.

*Remarks*.—*C. gibba* has a wide range both geologically and geographically. It has been recorded from the Gingin Chalk of Western Australia.

*Occurrence*.—Grice's Creek; very rare: Balcombe Bay; rare.

*CRISTELLARIA GEMMATA* Brady. (Pl. 20. fig. 62.)

*Cristellaria gemmata* Brady, 1881, p. 64; *Id.*, 1884, p. 554, pl. lxxi. figs. 6, 7.

*Remarks*.—This appears to be the first record of this species as a fossil. Brady's specimens came from off Fiji, Raine Island, and the Philippines.

*Occurrence*.—Altona Bay Coal Shaft; very rare.



*CRISTELLARIA PAUCICOSTULATA*, sp. nov. (Pl. 21. fig. 87.)

*Description*.—Test compressed, ovate, thin, with the whorls evolute. The outer whorl consisting of six chambers, separated by sharply salient to rounded sutural ribs; the surface of each segment flat or irregularly inflated, excepting the last which is moderately and evenly inflated. Sutures slightly curved in the early portion of the shell, the last three more strongly recurved exteriorly. Edge of test carinate. Apertural extremity prolonged into a short spout-like form.

*Dimensions*.—Length .76 mm.; width .52 mm.

*Relationships*.—This species falls into the “planulate” group with strong costæ as typified by *Cristellaria geminata* Brady and *C. bradyana* Chapman\*. From the former it differs in the completely evolute character of the test and fewer segments and from the latter in the fewer chambers and sharply salient costæ.

*Occurrence*.—Kackeraboite Creek; very rare.

*CRISTELLARIA RENIFORMIS* d'Orbigny. (Pl. 20. fig. 63.)

*Cristellaria reniformis* d'Orbigny, 1846, p. 88, pl. iii. figs. 39, 40; Brady, 1884, p. 539, pl. lxx. fig. 3 a, b.

*Remarks*.—D'Orbigny's specimens of *C. reniformis* came from the Miocene of Baden, near Vienna: the present appears to constitute the oldest record of this species. In the living state it is found in both Atlantic and Pacific Oceans, in temperate latitudes, at depths ranging from 150 to 2050 fathoms.

*Occurrence*.—Kackeraboite Creek; rare.

*CRISTELLARIA CONVERGENS* Bornemann. (Pl. 20. fig. 64.)

*Cristellaria convergens* Bornemann, 1855, p. 327, pl. xiii. figs. 16, 17; Brady, 1884, p. 546, pl. lxx. figs. 6, 7; Chapman, 1916, p. 32, pl. iii. fig. 21.

*Remarks*.—This species was described from the Oligocene of Germany and has been recorded by Howchin from the Lower Beds of Muddy Creek, Victoria. In the recent condition it is well distributed but never very common, its finest development being attained in very deep water. *C. convergens* is of fairly frequent occurrence in Antarctic dredgings.

*Occurrence*.—Balcombe Bay; very rare: Altona Bay Coal Shaft; very rare.

*CRISTELLARIA ARTICULATA* (Reuss). (Pl. 20. fig. 65.)

*Robulina articulata* Reuss, 1864, p. 53, pl. v. figs. 62 a, b.

*Cristellaria articulata* (Reuss), Brady, 1884, p. 547, pl. lxx. figs. 10-12; Chapman, 1916, p. 31, pl. ix. fig. 83.

*Remarks*.—The oldest record of this species is from the Cretaceous of Gingin, W.A. It was met with by Howchin in the Balcombian of Muddy

\* Chapman, 1894, p. 654, pl. x. figs. 13 a, b.

Creek, and is also found in the Victorian Miocene. *C. articulata* is a common form in the seas around New Zealand and south of Australia.

*Occurrence*.—Grice's Creek; common; Kackeraboite Creek; rare.

*CRISTELLARIA ORBICULARIS* (*d'Orbigny*). (Pl. 20. fig. 66.)

*Robulina orbicularis* d'Orbigny, 1826, p. 288, pl. xv. figs. 8, 9.

*Cristellaria orbicularis* (d'Orb.), Brady, 1884, p. 549, pl. lxi. fig. 17.

*Remarks*.—This keeled form of *C. vortex* has been recorded from the Miocene of the Vienna Basin and the Pliocene of Italy. It is found in water of moderate depth around New Zealand and off the south coast of Australia.

*Occurrence*.—Kackeraboite Creek; rare.

*CRISTELLARIA ROTULATA* (*Lamarck*). (Pl. 21. fig. 67.)

*Lenticulites rotulata* Lamarck, 1804, p. 188, No. 3; *Id.*, 1816, pl. cccclxvi. fig. 5.

*Cristellaria rotulata* (Lam.), Chapman, 1904, p. 102, pl. xxii. fig. 9; Cushman, 1923, p. 108, pl. xxii. fig. 2; pl. xxviii. figs. 1, 2.

*Remarks*.—The geological range of this widely distributed species extends from the Lias to the present day, its oldest record in Australia being from the Jurassic of Greenough River, W.A. (Chapman). In the living condition it is found at all depths and in every ocean.

*Occurrence*.—Grice's Creek; frequent: Balcombe Bay; very rare: Kackeraboite Creek; very rare.

*CRISTELLARIA CULTRATA* (*Montfort*). (Pl. 21. fig. 68.)

*Robulus cultratus* Montfort, 1808-10, p. 214, 54<sup>m</sup> genre.

*Cristellaria cultrata* (Mont.), Brady, 1884, p. 550, pl. lxx. figs. 4-6; Cushman, 1913, p. 64, pl. xxix. fig. 4.

*Remarks*.—This well-known species has a geological range and distribution in the recent condition similar to that of *C. rotulata*. Australian records are from the Chalk of Gingin, W.A., the Oligocene of Muddy Creek, the Miocene of Batesford and the Mallee Bores.

*Occurrence*.—Grice's Creek; very common: Balcombe Bay; frequent: Kackeraboite Creek; common: Altona Bay (Coal Shaft); common.

*CRISTELLARIA CALCAR* (*Linné*). (Pl. 21. fig. 69.)

*Nautilus calcar* Linné, 1767, p. 1162, No. 272.

*Cristellaria calcar* (Linné), Brady, 1884, p. 551, pl. lxx. figs. 9-15; Cushman, 1923, p. 115, pl. xxx. fig. 7; pl. xxxi. figs. 4, 5.

*Remarks*.—The only previous record of *C. calcar* from Australia appears to be that of Heron-Allen and Earland from the Miocene of Batesford. It occurs in beds of Tertiary age elsewhere. In recent dredgings it has been found in the Atlantic and Pacific Oceans, usually in warm water.

*Occurrence*.—Kackeraboite Creek; common (small): Altona Bay (Coal Shaft); rare.

**CRISTELLARIA ORNATA** (*d'Orbigny*). (Pl. 21. fig. 70.)*Robulina ornata* d'Orbigny, 1846, p. 98, pl. iv. figs. 16, 17.

*Remarks*.—This is a species of the *Cristellaria mamilligera* group, but with broken costæ. Besides its record from the Miocene of the Vienna Basin it has been found by Fornasini in the shore sands of Lido, Rimini, on the Adriatic. Terquem's and Hantken's species of the same name are homonyms.

*Occurrence*.—Grice's Creek; common.

## Subfamily POLYMORPHINÆ.

Genus POLYMORPHINA *d'Orbigny*.**POLYMORPHINA GIBBA** *d'Orbigny*. (Pl. 21. fig. 71.)*Polymorphina (Globulina) gibba* d'Orbigny, 1826, p. 266, No. 20, Modèle No. 63.*Polymorphina gibba* d'Orb., Brady, 1884, p. 501, pl. lxxi. figs. 12 a, b; Chapman, 1913, p. 85, pl. xli. fig. 4.

*Remarks*.—*P. gibba* is found in fossiliferous deposits from the Jurassic to the present day. Howchin has recorded it from the Lower Beds (Oligocene) of Muddy Creek. It is very widely distributed as a living form.

*Occurrence*.—Altona Bay Coal Shaft; rare.

**POLYMORPHINA COMMUNIS** *d'Orbigny*. (Pl. 21. fig. 72.)*Polymorphina (Guttulina) communis* d'Orbigny, 1826, p. 266, pl. xii. figs. 1-4, Modèle No. 62.*Polymorphina communis* d'Orb., Brady, 1884, p. 568, pl. lxxii. fig. 19.

*Remarks*.—This shallow-water form is widely distributed in both the fossil and living condition, its oldest record being from the Lower Lias.

*Occurrence*.—Grice's Creek; very rare: Altona Bay Coal Shaft; very rare.

**POLYMORPHINA COMPRESSA** *d'Orbigny*, var. *MARGINALIS* Jones & Chapman. (Pl. 21. fig. 73.)*Polymorphina compressa* d'Orb., fistulose form, Brady, 1884, p. 566, pl. lxxiii. fig. 17.*Polymorphina compressa* d'Orb., var. *marginatis* Jones & Chapman, 1896, p. 506, fig. 37 (in text).

*Remarks*.—Fistulose specimens of *Polymorphine* are of frequent occurrence in the Victorian Tertiaries, probably as the result of the very favourable conditions under which the foraminifera existed. This variety of *P. compressa* is also found in the Miocene of Batesford.

*Occurrence*.—Grice's Creek; very rare.

**POLYMORPHINA ACUMINATA** (*d'Orbigny*). (Pl. 21. fig. 74.)*Pyrulina acuminata* d'Orbigny, 1840, p. 43, pl. iv. figs. 18, 19; facsimile in Science Gossip, 1870, p. 157, fig. 15 a.*Polymorphina acuminata* (d'Orb.), Brady, 1878, p. 435, pl. xx. figs. 5 a, b.

*Remarks*.—Previous records of this species as a fossil are from the Chalk

of Meudon, France; the Chalk-Marl of Charing, Kent; and the Oligocene of North Germany. In the living condition it has been recorded from Baffin's Bay, at a depth of 57 fathoms.

*Occurrence*.—Grice's Creek; very rare.

**POLYMORPHINA ANGUSTA** *Egger*. (Pl. 21. fig. 75.)

*Polymorphina (Globulina) angusta* Egger, 1857, p. 290, pl. xiii. figs. 1-3.

*Polymorphina angusta* Egger, Brady, 1884, p. 563, pl. lxxii. figs. 1-3; Chapman, 1917, p. 34, pl. x. fig. 93.

*Remarks*.—This species occurs in fossiliferous deposits from the Upper Cretaceous to the present day. Its oldest Australian occurrence is in the Gingga Chalk. Recent records are from the Atlantic and Pacific Oceans, from depths of 2400 fathoms and upwards.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

**POLYMORPHINA GLANDULINOIDES** *Fornasini*. (Pl. 21. fig. 76.)

*Polymorphina vitrea* (Bornemann), var. *glandulinoides* Fornasini, 1901, p. 66, woodcut, fig. 18.

*Remarks*.—This species is easily confused with *Nodosaria (Glandulina) levigata* d'Orb., but on moistening the test the Polymorphine arrangement of the chambers is easily seen. *P. glandulinoides* was previously known from the Italian Tertiaries.

*Occurrence*.—Altona Bay Coal Shaft; very rare.

**POLYMORPHINA RUGOSA** *d'Orbigny*, var. *horrida* *Reuss*. (Pl. 21. figs. 78, 79.)

*Polymorphina* spp., var. *horrida* Reuss, Jones & Chapman, 1896, p. 502, figs. 10-16 (in text).

*Remarks*.—This variety, as attached to *P. rugosa*, does not appear to have been recorded previously. It falls into the var. *horrida* group of Messrs. Jones and Chapman as the fistulosity takes the form of an apical cluster of tubes. It is worthy of note that every specimen of *P. rugosa* found belonged to this variety.

*Occurrence*.—Grice's Creek; rare: Kackeraboite Creek; rare.

**POLYMORPHINA ELEGANTISSIMA** *Parker & Jones*. (Pl. 21. fig. 77.)

*Polymorphina elegantissima* Parker & Jones, 1865, table x. p. 438; Brady, 1884, p. 566, pl. lxxii. figs. 12-15; Cushman, 1921, p. 267, pl. liv. figs. 1, 2.

*Remarks*.—This species is of very common occurrence in Australian Tertiary deposits and in the living condition is practically confined to Australian waters, from which it was first described. It has, however, been found by Dr. Egger off the west coast of Africa, and in the fossil condition its oldest record is that of Halkyard from the Eocene marls of Biarritz. It also occurs in the Tertiary of the Coastal Plain of United States (Cushman).

*Occurrence*.—Kackeraboite Creek; rare: Altona Bay Coal Shaft; very rare.

Genus *UVIGERINA* d'Orbigny.*UVIGERINA PYGMÆA* d'Orbigny. (Pl. 21. fig. 80.)*Uvigerina pygmaea* d'Orbigny, 1826, p. 269, pl. xii. figs. 8, 9.*Uvigerina pygmaea* d'Orb., Brady, 1884, p. 575, pl. lxxiv. figs. 11-14; Cushman, 1913, p. 96, pl. xlii. fig. 1, pl. xliv. fig. 5.

*Remarks.*—The geological range of this species is from the Eocene (of Biarritz) to the present day. It is found in every ocean, but is most abundant in cold water. In the Port Phillip area it is confined to the Grice's Creek Beds, in which it is a very common and characteristic species.

*Occurrence.*—Grice's Creek ; very common.

*UVIGERINA PYGMÆA* d'Orb., var. *MACILENTA*, nov. (Pl. 21. fig. 81.)

*Remarks.*—This varietal form differs from the typical species in the absence of the strongly costate surface, the only indication of the character being a slight wrinkling of the aboral end, with the cultrate margins of the early segments. In point of size it agrees with the type species.

*Occurrence.*—Grice's Creek ; frequent.

*UVIGERINA SCHWAGERI* Brady. (Pl. 21. fig. 82.)*Uvigerina schwageri* Brady, 1884, p. 575, pl. lxxiv. figs. 8-10; Cushman, 1921, p. 270, pl. lv. figs. 3-5 a, b.

*Remarks.*—This species appears to be known in the recent condition only. Previous records have been from the Arabian Sea, Fiji, Torres Strait, and around the Philippines, where it is very common.

*Occurrence.*—Grice's Creek ; frequent.

*UVIGERINA TENUISTRIATA* Reuss. (Pl. 21. fig. 83.)*Uvigerina tenuistriata* Reuss, 1870, p. 485; *Ag.* von Schlicht, 1870, pp. 65, 66, pl. xxii. figs. 34-36; Brady, 1884, p. 574, pl. lxxiv. figs. 4-7.

*Remarks.*—The oldest record of *U. tenuistriata* is that of Halkyard from the Eocene of Biarritz. It has also occurred in the Miocene of Batesford, and the Lower Pliocene of the Mallee Bores, both in Victoria. In the recent condition it has been found off the coast of Patagonia, Raine Island, and around the Philippines.

*Occurrence.*—Grice's Creek ; very rare: Kackeraboite Creek ; very rare: Altona Bay Coal Shaft ; common.

*UVIGERINA INTERRUPTA* Brady. (Pl. 21. fig. 84.)*Uvigerina interrupta* Brady, 1879, p. 274, pl. viii. figs. 17, 18; *Id.*, 1884, p. 580, pl. lxxv. figs. 12-14; Cushman, 1913, p. 103, pl. xliv. fig. 1.

*Remarks.*—This species has not previously occurred in beds of greater age than the Miocene, in strata of which epoch it is not uncommon in Victoria. In the recent condition it is confined to the Pacific Ocean, most of the records being from tropical waters.

*Occurrence.*—Kackeraboite Creek ; very rare: Altona Bay Coal Shaft ; rare.

## Subfamily RAMULININÆ.

Genus RAMULINA *Rupert Jones.*RAMULINA ACULEATA *Wright.* (Pl. 21. fig. 85.)

*Ramulina aculeata* Wright, 1886, p. 331, pl. xxvii. fig. 11; Jones & Chapman, 1897, p. 345, figs. 23-42 (in text); Chapman, 1917, p. 36, pl. x.

*Remarks.*—This species is usually found in strata of Upper Cretaceous age, but has also occurred as early as the Jurassic of Switzerland (*Haeussler*), and in beds of Miocene age in Europe. It is also well distributed in the Gault (Albien) of Folkestone. The only previous record of *R. aculeata* from Australia is that of one of us (F. C.) from the Gipping Chalk.

*Occurrence.*—Grice's Creek; very rare.

RAMULINA GLOBULIFERA *Brady.* (Pl. 21. fig. 86.)

*Ramulina globulifera*, Brady, 1879, p. 272, pl. viii. figs. 32, 33; *Id.*, 1884, p. 587, pl. lxxvi. figs. 22-28; Jones & Chapman, 1897, p. 340, figs. 5-22 (in text).

*Remarks.*—The geological range of this species is from the Jurassic to the present day. It has been noted by Heron-Allen and Earland as occurring in the Miocene limestone of the Filter Quarries at Batesford. In the recent condition it has been recorded from the Arabian Sea, off New Zealand, round the Philippines and elsewhere.

*Occurrence.*—Altona Bay Coal Shaft; very rare: Kackeraboite Creek; very rare.

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## EXPLANATION OF THE PLATES.

## PLATE 17.

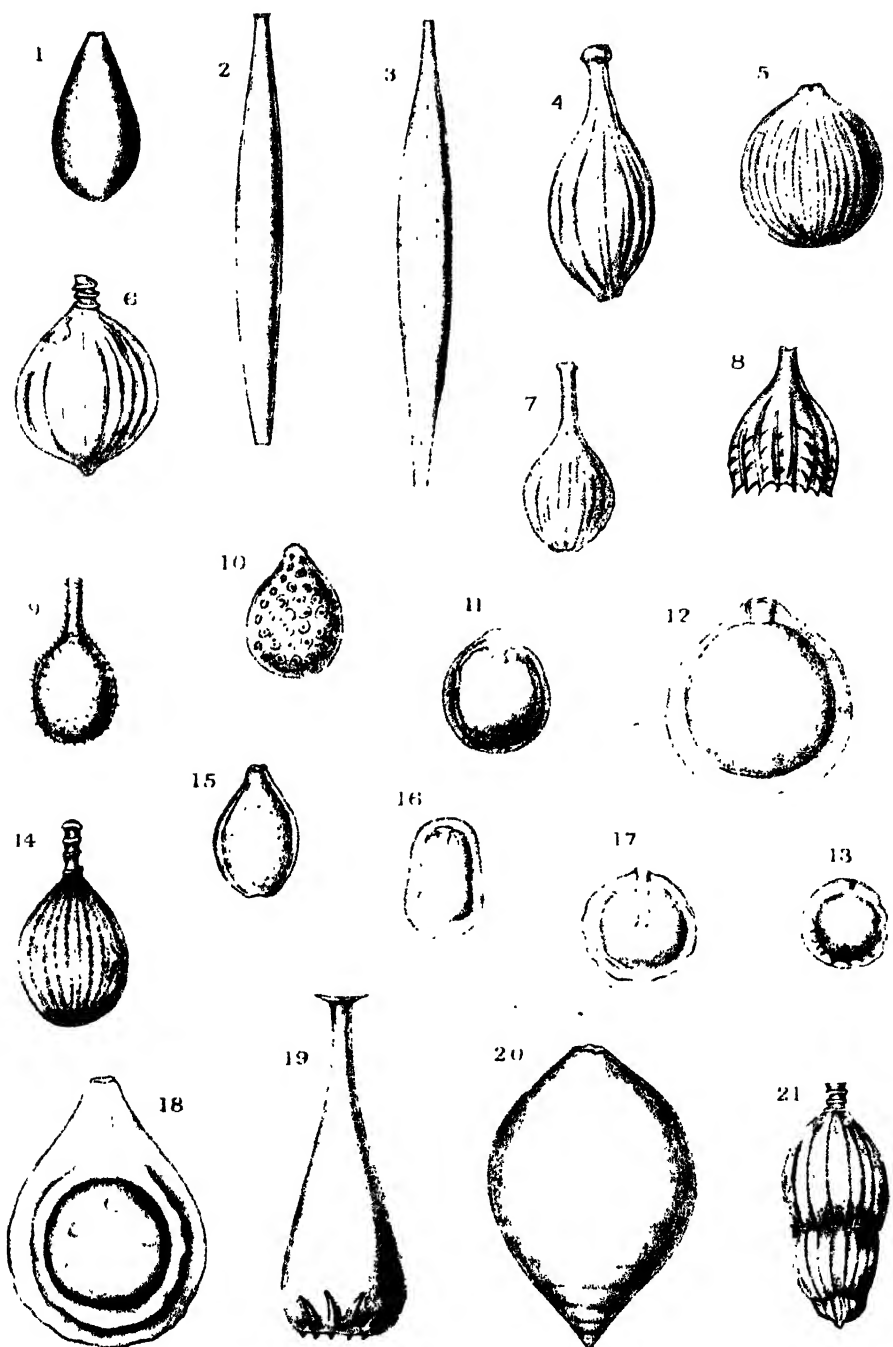
- Fig. 1. *Lagena lævis* (Montagu). Altona Bay Coal Shaft. × 26.  
 2. " *elongata* (Ehrenberg). Grice's Creek. × 52.  
 3. " *distoma* Parker & Jones. Altona Bay Shaft. × 52.  
 4. " *gracilis* Williamson. Grice's Creek. × 52.  
 5. " *striata* (d'Orb.). Grice's Creek. × 52.  
 6. " *sulcata* (W. & J.). Balcombe Bay. × 52.  
 7. " *sulcata*, var. *interrupta* Will. Altona Bay Coal Shaft. × 52.  
 8. " *plumigera* Brady. Altona Bay Coal Shaft. × 52.  
 9. " *hispida* Reuss. Balcombe Bay. × 52.  
 10. " *favoso-punctata* Brady. Altona Bay Coal Shaft. × 52.  
 11. " *annectens* Burrows & Holland. Altona Bay Coal Shaft. × 52.  
 12. " *marginata* (W. & B.). Grice's Creek. × 52.  
 13. " *marginata*, var. *cutenulosa* Chapman. Grice's Creek. × 52.  
 14. " *marginato-perforata* Seg. Altona Bay Coal Shaft. × 104.  
 15. " *schlichti* (A. Silv.). Grice's Creek. × 52.  
 16. " *quadrata* (Will.). Altona Bay Coal Shaft. × 52.  
 17. " *orbignyana* (Seg.). Balcombe Bay. × 52.  
 18. " *lacunata* Burrows & Holland. Altona Bay Coal Shaft. × 52.  
 19. " *semistriata* Will. Altona Bay Coal Shaft. × 104.  
 20. *Nodosaria* (*Glandulina*) *lævigata* d'Orb. Grice's Creek. × 52.  
 21. " *scalaris* (Batsch). Balcombe Bay. × 52.

## PLATE 18.

- Fig. 22. *Nodosaria scalaris*, var. *separens* Brady. Altona Bay Coal Shaft. × 52.  
 23. " *longiscata* d'Orb. Balcombe Bay. × 52.  
 24. " *ovicula* d'Orb. Kackeraboite Creek. × 52.  
 25. " *hispida* d'Orb. Grice's Creek. × 52.  
 26. " *fistuca* Schwager. Balcombe Bay. × 26.  
 27. " *raphanus* (Linn.). Grice's Creek. × 26.  
 28. " *vertebralis* (Batsch). Balcombe Bay. × 26.  
 29. " *raphanistrum* (Linn.). Altona Bay Coal Shaft. × 8.  
 30. " *badensis* d'Orb. Grice's Creek. × 13.  
 31. " (*Dentalina*) *communis* (d'Orb.). Altona Bay Coal Shaft. × 26.  
 32. " " *elegantissima* (d'Orb.). Altona Bay Coal Shaft. × 52.  
 33. " " *consobrina* (d'Orb.). Kackeraboite Creek. × 26.  
 34. " " " var. *emaciata* Reuss. Grice's Creek. × 26.

## PLATE 19.

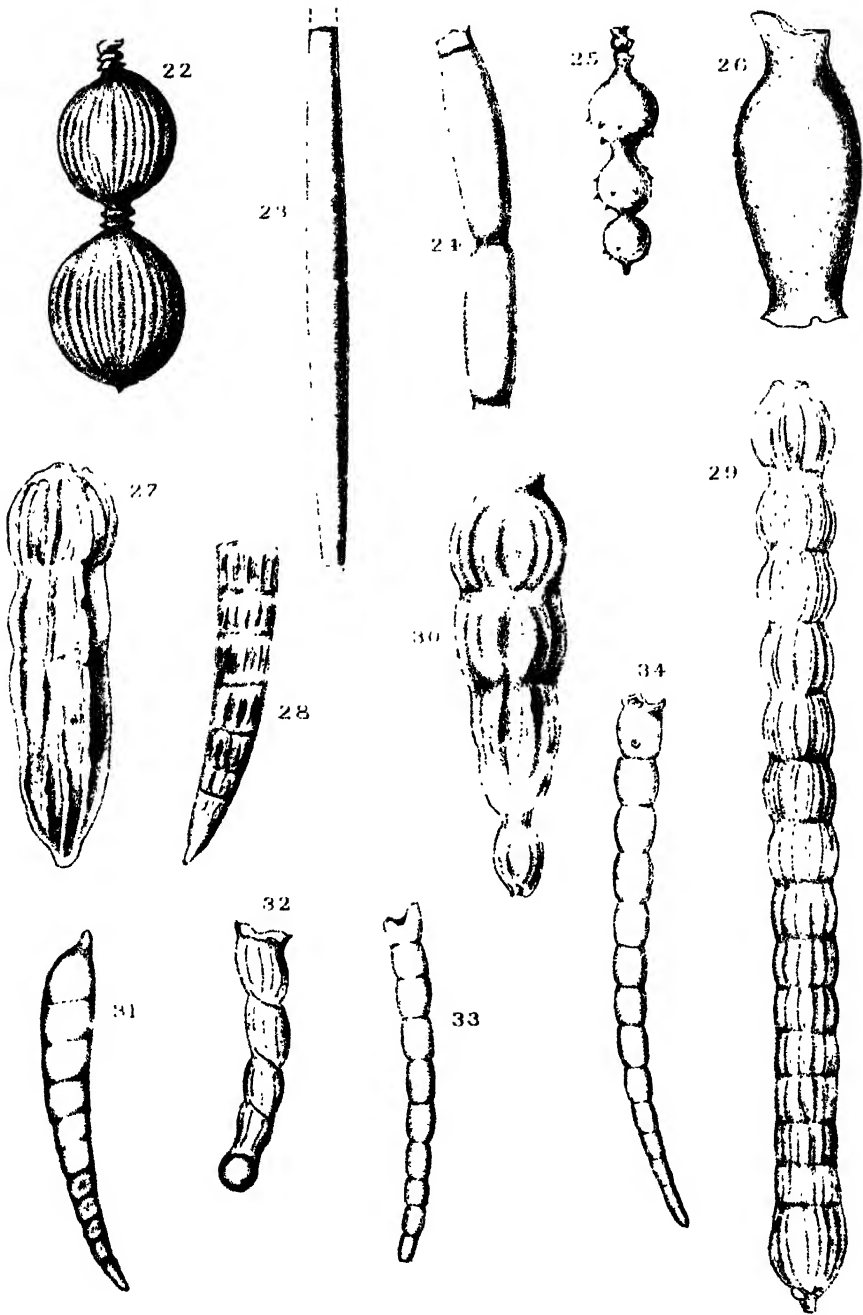
- Fig. 35. *Nodosaria* (*Dentalina*) *boueana* (d'Orb.). Grice's Creek. × 26.  
 36. " " *lorneiana* (d'Orb.). Grice's Creek. × 26.  
 37. " " *farcimen* (Reuss). Grice's Creek. × 26.  
 38. " " *pauperata* (d'Orb.). Grice's Creek. × 26.  
 39. " " *roemeri* (Neug.). Balcombe Bay. × 26.  
 40. " " *soluta* (Reuss). Grice's Creek. × 26.  
 41. " " *retrorsa* (Reuss). Grice's Creek. × 26.  
 42. " " *pyrula*, var. *semirugosa* d'Orb. Grice's Creek. × 52.



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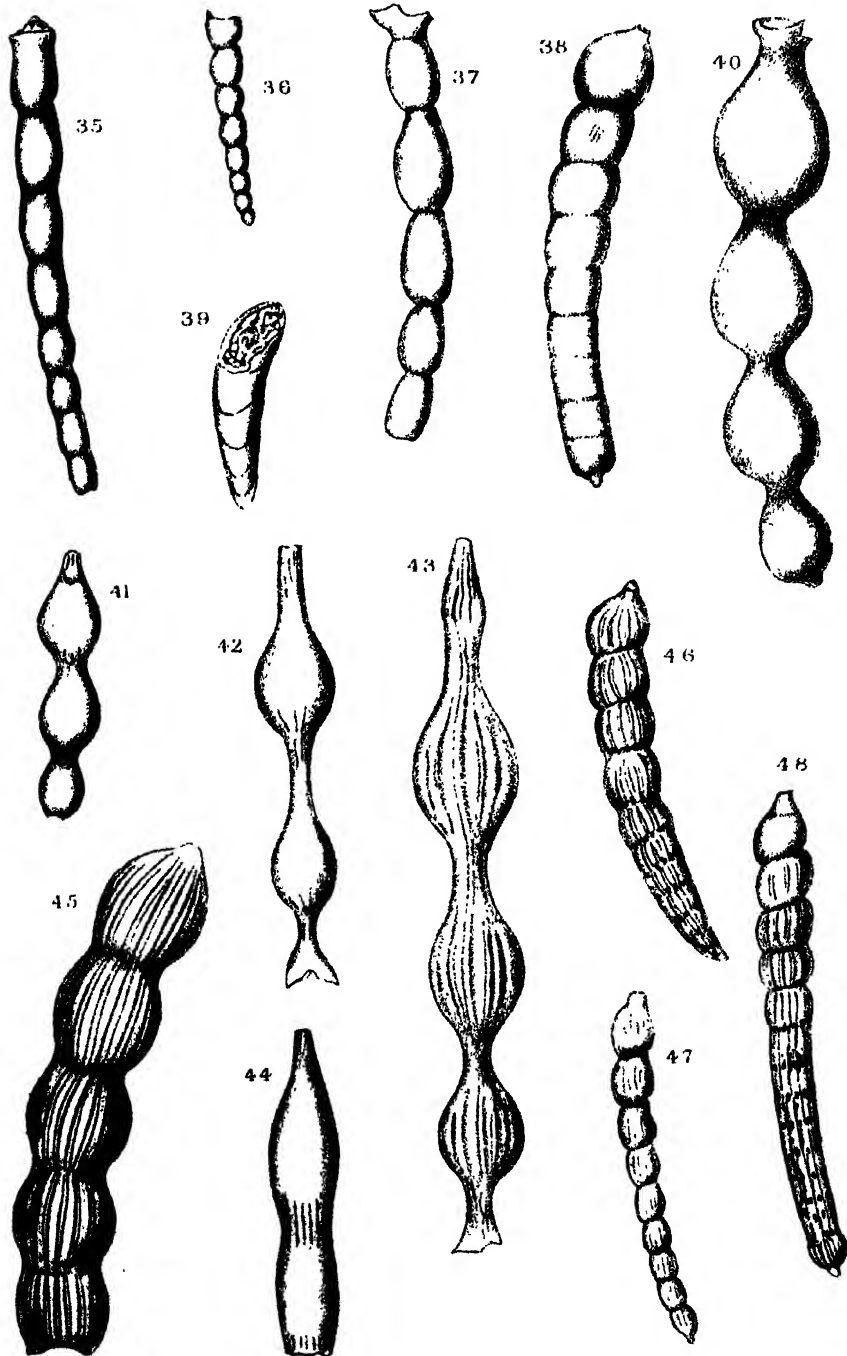




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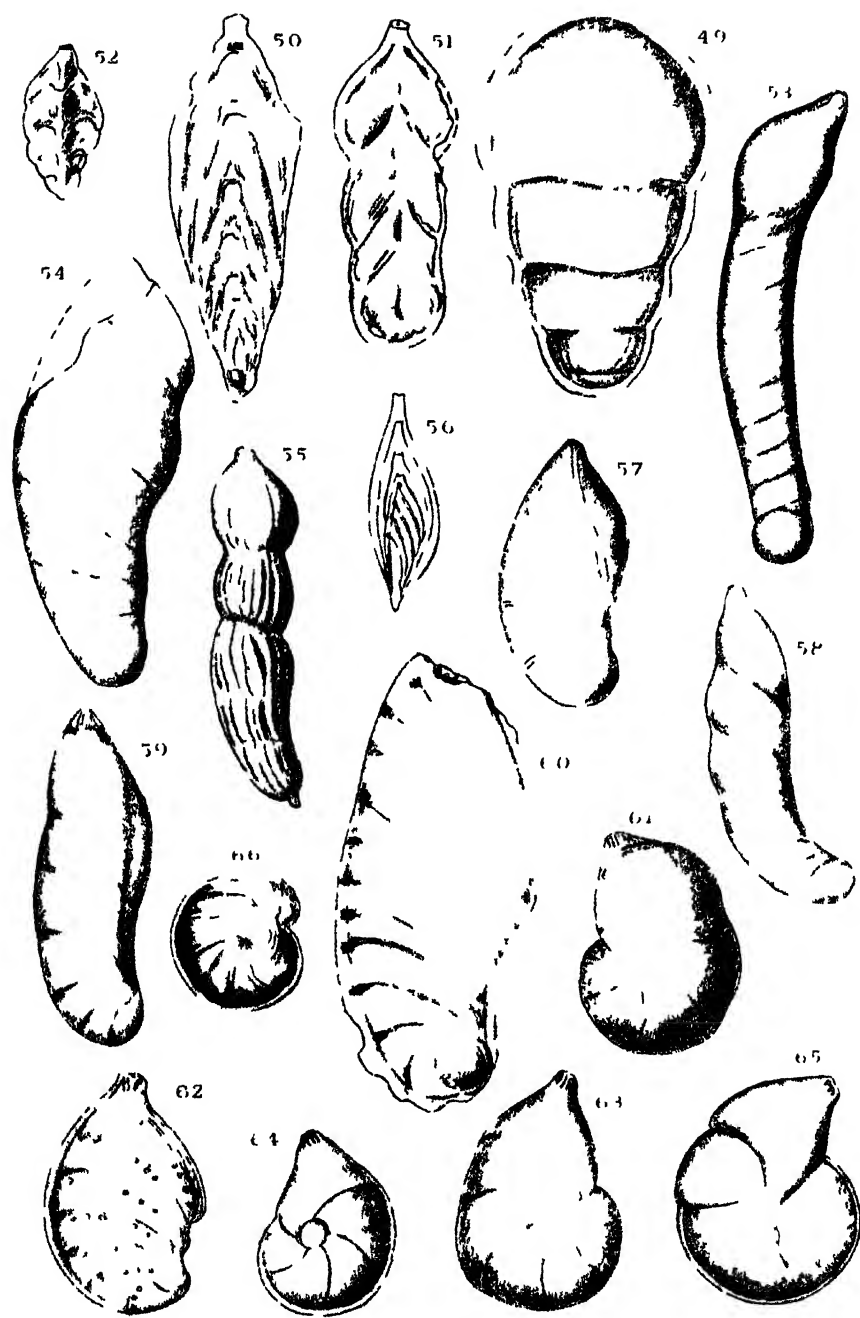
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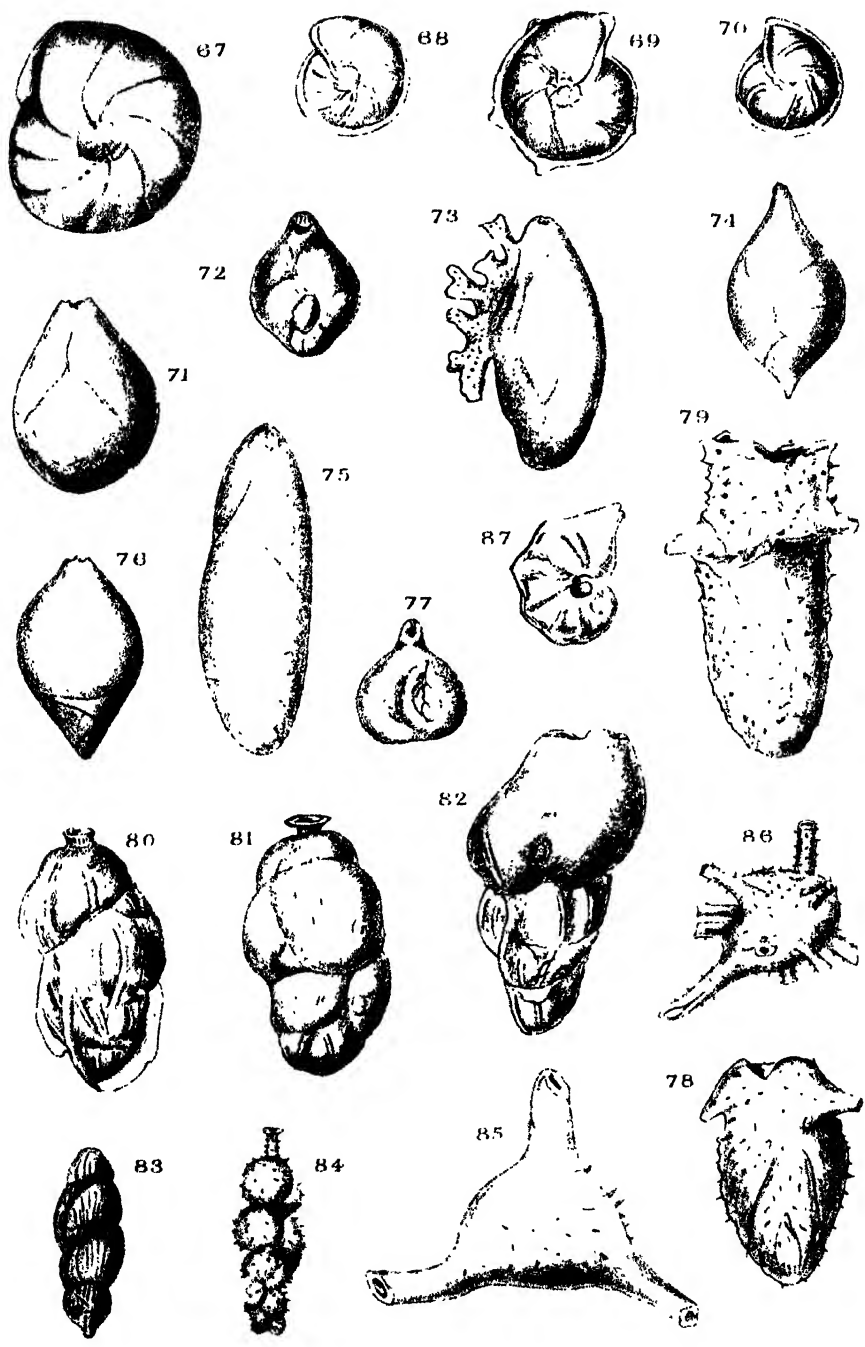






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F. Chapman ad nat. det.

VICTORIAN TERTIARY FORAMINIFERA



Fig. 43. *Nodosaria (Dentalina) pyrula*, var. *longicostata* Cushman. Kackeraboite Creek. × 52.

- 44. " " *semiplicata* (d'Orb.). Altona Bay Coal Shaft. × 52.
- 45. " " *fissicostata* (Gümbel). Kackeraboite Creek. × 13.
- 46. " " *obliqua* (Linn.). Grice's Creek. × 13.
- 47. " " *multilineata* (Born.). Grice's Creek. × 26.
- 48. " " *acuta* (d'Orb.). Altona Bay Coal Shaft. × 13.

#### PLATE 20.

- Fig. 49. *Lingulina seminuda* Hantken. Balcombe Bay. × 13.
- 50. *Frondicularia inæqualis* Costa. Grice's Creek. × 52.
  - 51. " *compta* Brady. Grice's Creek. × 52.
  - 52. *Trifarina bradyi* Cushman. Balcombe Bay. × 52.
  - 53. *Vaginulina legumen* (Linn.). Grice's Creek. × 52.
  - 54. *Marginulina glabra* d'Orb. Balcombe Bay. × 26.
  - 55. " *costata* (Batsch). Balcombe Bay. × 26.
  - 56. *Flabellina oolithica* Deecke. Grice's Creek. × 26.
  - 57. *Cristellaria crepidula* (F. & M.). Grice's Creek. × 52.
  - 58. " " var. *gladius* Phil. Balcombe Bay. × 26.
  - 59. " *protracta* Born. Balcombe Bay. × 52.
  - 60. " *elongata* d'Orb. Altona Bay Coal Shaft. × 26.
  - 61. " *gibba* d'Orb. Balcombe Bay. × 52.
  - 62. " *gemmata* Brady. Altona Bay Coal Shaft. × 52.
  - 63. " *reniformis* d'Orb. Kackeraboite Creek. × 26.
  - 64. " *convergens* Born. Balcombe Bay. × 52.
  - 65. " *articulata* Reuss. Grice's Creek. × 52.
  - 66. " *orbicularis* (d'Orb.). Kackeraboite Creek. × 26.

#### PLATE 21.

- Fig. 67. *Cristellaria rotulata* (Lam.). Grice's Creek. × 26.
- 68. " *cultrata* (Montf.). Grice's Creek. × 26.
  - 69. " *calcar* (Linn.). Kackeraboite Creek. × 52.
  - 70. " *ornata* (d'Orb.). Grice's Creek. × 26.
  - 71. *Polymorphina gibba* d'Orb. Altona Bay Coal Shaft. × 26.
  - 72. " *communis* d'Orb. Altona Bay Coal Shaft. × 52.
  - 73. " *compressa* d'Orb., var. *marginalis* Jones & Chapm. Grice's Creek. × 52.
  - 74. " *acuminata* d'Orb. Grice's Creek. × 52.
  - 75. " *angusta* Egger. Altona Bay Coal Shaft. × 52.
  - 76. " *glandulinoides* Fornasini. Altona Bay Coal Shaft. × 52.
  - 77. " *elegantissima* Parker & Jones. Altona Bay Coal Shaft. × 52.
  - 78, 79. " *rugosa* d'Orb., var. *horrida* Reuss. Grice's Creek. × 52.
  - 80. *Uvigerina pygma* d'Orb. Grice's Creek. × 52.
  - 81. " var. *macilenta* nov. Grice's Creek. × 52.
  - 82. " *schwageri* Brady. Grice's Creek. × 52.
  - 83. " *tenuistriata* Reuss. Altona Bay Coal Shaft. × 52.
  - 84. " *interrupta* Brady. Altona Bay Coal Shaft. × 52.
  - 85. *Ramulina aculeata* Wright. Grice's Creek. × 52.
  - 86. " *globulifera* Brady. Altona Bay Coal Shaft. × 26.
  - 87. *Cristellaria paucicostulata*, sp. nov. Kackeraboite Creek. × 26.



On the Post-Embryonic Development of the Fairy Shrimp (*Chirocephalus diaphanus*). By H. GRAHAM CANNON, M.A., D.Sc., F.L.S., Professor of Zoology, Sheffield University.

(PLATES 22 & 23 and 3 Text-figures.)

[Read 4th March, 1926.]

### *Introduction.*

THIS study of the post-embryonic development of *Chirocephalus diaphanus* was undertaken primarily with the object of comparing it with the development of *Estheria*, which I described in 1924. No account of the development, as far as I am aware, has hitherto been published, but the embryology of the nearly allied Anostraca, *Branchipus* and *Artemia*, has been dealt with in considerable detail by Claus (1886). In this work no mention is made of a segmentally arranged series of coelomic cavities such as occurs so prominently in *Estheria*. It seemed probable that a renewed investigation of the development of an Anostracan might demonstrate that here too coelomic sacs are found, but developed to a lesser extent. This I found actually to be the case.

I have made no attempt to work out the complete embryology in detail, as this does not seem to be called for, but the work has led on to some interesting observations on the musculature and antennal gland, and the main part of the paper deals with these.

The material for the investigation was obtained from two sources. Mr. H. G. Hurrell, M.A., has for the last six years supplied me with dried mud obtained from ponds on Dartmoor, and from this I have reared larvæ in the laboratory. In addition, Mr. E. R. Speyer, M.A., kindly handed over to me a year ago an almost complete series of sections of all stages from the egg up to the adult. I wish to express my thanks to both these gentlemen for supplying me with the material.

The larvæ that I reared myself were fixed in cold "Flemming without Acetic" and the results left very little to be desired. Mr. Speyer's material was fixed in a sublimate fixative. This did not fix the cytoplasm at all well, but was extremely useful for the study of developing muscle-fibrils.

The technique employed for sectioning, etc. was the same as that used for *Estheria* (1924, p. 396).

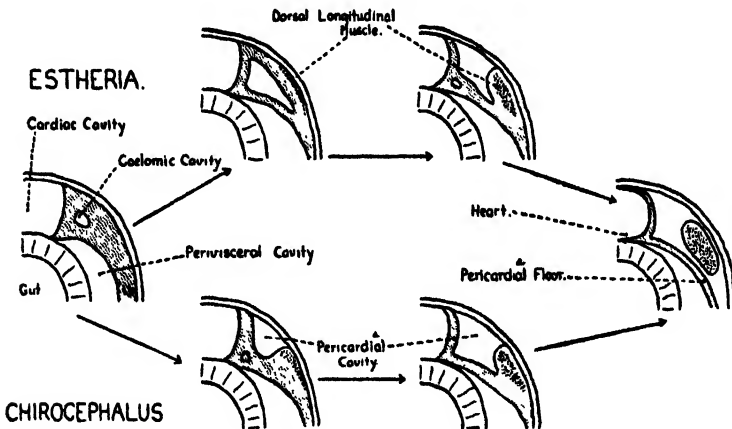
### *Early Development and Heart Formation.*

The larva of *Chirocephalus* usually hatches from the egg as an early metanauplius in which two or three trunk segments are visible. It may, however, hatch as a true nauplius, that is, with no signs of segmentation in the post-mandibular region. On the other hand, it sometimes exhibits as many as

six or seven distinct trunk segments while still in the egg-membrane. The conditions which control the stage at which the larva hatches are not at all clear. Usually in any culture the individuals all hatch at the same stage, although there may be a few eggs that hatch days or even weeks after the others.

The nauplius exhibits the same main features as that of *Estheria*. Its early development is also very similar. The post-mandibular region appears as a solid mass, the mesoderm filling the space between endoderm and ectoderm. The dorsal split in the mesoderm forming the cardiac cavity appears distinctly before the ventral perivisceral space—a slight difference from *Estheria* where the two appear together.

TEXT-FIG. 1.



A diagram comparing the development and fate of the coelomic sacs in *Chirocephalus* and *Estheria*.

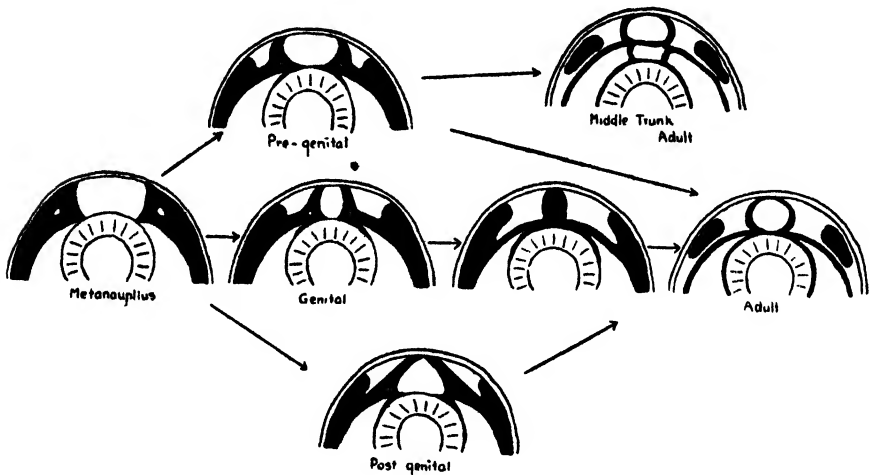
The transient ventral segmentation that I described in *Estheria* (1924, p. 401) can also be seen in *Chirocephalus*, but anteriorly, owing to the very rapid differentiation of the limb muscles, it is difficult to observe. Posteriorly, however, it is very clear and can easily be seen in a larva as long as 1.5 mm.

The method of heart-formation, especially in the anterior trunk-segments, is essentially the same as that of *Estheria* (text-fig. 1). Coelomic sacs are formed, but do not attain any considerable size owing to the precocious development of the pericardial cavity (Pl. 22. fig. 5). In *Estheria*, the coelomic sacs develop to a considerable size, exhibiting very conspicuous cavities, before their walls shrink inwards away from the adjacent ectoderm to form the pericardial space, and, previous to this shrinkage, the dorsal longitudinal muscle-fibrils are differentiated on the outer surface of the outer wall of the pouches. In *Chirocephalus* the more dorsal parts of the outer



walls of the sacs commence to sink in almost directly after the appearance of the segmental cavities, so that these latter very early become obliterated. The more ventral parts of the outer walls remain in contact with the ectoderm and from them are later differentiated the dorsal longitudinal muscles. But here, again, the differentiation takes place comparatively very early. The cells of the outer face of the somites elongate and arrange themselves in rows preparatory to the formation of the muscles as soon as, or even before, the appearance of the cœlomic cavity, as can be seen in fig. 1 (Pl. 22). Comparison of this figure with fig. 22 (pl. 24) of my *Estheria* paper (1924), which both represent frontal sections through similar stage larvæ, gives a good idea of the time differences in the various processes connected with heart-formation in the two forms. In the *Estheria* figure

TEXT-FIG. 2.



A diagram comparing the methods of heart-formation in the various regions of *Chirocephalus*.

the cœlomic sacs are large, and neither pericardial cavity nor dorsal longitudinal muscle have appeared. In the *Chirocephalus* figure the segments in the middle region show both, while in the anterior segments the cœlomic cavities have already become obliterated.

The methods of heart-formation differ in different regions of the body, but all can be traced as modifications of the process as exhibited in *Estheria* (text-fig. 2). In the most anterior part, that is, just posterior to the mandibular region, as the pericardial cavity is being formed the inner angles of the cœlomic sacs grow inwards comparatively rapidly to meet each other over the dorsal surface of the gut, and so form the floor of the heart-tube. In the most posterior part of the body it is the upper angles that

grow inwards first of all, the inner angles remaining in contact with the dorso-lateral part of the gut, so that here the roof of the heart is formed before the floor. In the middle region of the body, about the region of the genital segment, both upper and inner angles grow inwards together, to such an extent as completely to close the cardiac cavity. Thus at one stage—in a larva about 1.75 mm. in length—there is a part of the heart that appears simply as a solid plug of cells. Immediately anterior to this the floor of the heart is formed but not the roof, while immediately posterior to it the roof is formed but not the floor. The cells forming this "cardiac plug" show a bilateral arrangement, and it is possible that in the living larvæ there is a narrow split extending between them, but in transverse sections this is not obvious. When the larvæ grow to about the length of 2 mm. a tubular cavity reappears in the "cardiac plug," so that the cavity of the heart-tube becomes continuous as in the adult.

The process of heart-formation in *Chirocephalus*, considered as a whole, is undoubtedly less primitive than that of *Estheria*, and for two main reasons. First, since the Crustacea evolved from forms in which there was a large perivisceral coelom, the occurrence of large coelomic sacs during development can be taken to indicate a more ancestral condition than that in which they are small or completely suppressed. And secondly, since the more primitive Crustacea exhibit a greater degree of homomerism than the more specialized, it is clear that, if the method of heart-formation in any segment is considered as a distinct merome, a process of heart-formation that is the same in all segments, as in *Estheria*, is more primitive than one which is different in different parts of the body as in *Chirocephalus*. The occurrence of various methods of heart-formation in the various regions of the body I take simply to indicate the progressive degree of heteromerism that is exhibited in the evolution of the higher Crustacea from the lower. The heart certainly is practically the same structurally throughout its length, in *Chirocephalus* just as in *Estheria*, but the development of the ventral mesoderm is different in the post-genital apodous portion from that of the more anterior limb-bearing region, and probably the different processes of heart-formation are correlated with this. The temporary closure of the heart of *Chirocephalus* is thus probably of little importance, being merely a "mechanical" result of its specialized development.

The ostia are formed as in *Estheria*, that is, they are not the persistent slits in between successive coelomic sacs, but they are lateral gaps that are re-formed in the intersegmental planes after the coelomic sacs have formed the continuous heart-tube. At least this is their method of formation in the more anterior parts of the heart where the coelomic sacs fuse up very early. Posteriorly the sacs remain separate much longer and it is possible that, in this region, the ostia are the persistent gaps between them, but I have not settled this point with certainty.

In *Estheria* I showed that the circular muscles of the gut grow down from the attachments of the inner corners of the coelomic sacs to the gut, at a comparatively late stage in the development, the only "musculature" on the mid-gut up to this stage being the thin strands running anteriorly from the proctodæal circular muscles. These latter strands occur also in *Chirocephalus*, but in this form the circular muscles are formed at a comparatively early stage. Otherwise they develop just as in *Estheria*.

There is a slight difference in the attachment of the heart to the dorsal wall of the gut. Anteriorly and posteriorly the heart remains in contact with the gut, but in the middle region it becomes lifted up almost directly the floor of the heart has developed and before the roof has formed (Pl. 23. fig. 8). It retains connections with the gut-wall laterally by the cells which grow down to form the circular musculature. There is thus formed a tubular space underlying the heart and between it and the gut (text-fig. 2).

#### *The Antennal and Maxillary Glands.*

The antennal gland, which is fully formed in the newly hatched larva, is very similar in structure to that of *Estheria*. The duct cells exhibit slight differences. Thus they often project through the sphincter as a sort of cone into the end sac. The duct itself, at the posterior limit of the loop, sometimes exhibits lageniform outgrowths that may be separated from the lumen and so occur as thick-walled vesicles in the cytoplasm.

The most interesting point, however, in the anatomy of the gland is that the three sphincter cells surrounding the entrance of the duct into the end-sac can be seen very clearly to be connected directly with the cuticle (Pl. 22. fig. 2). The sphincter is thus similar to that which I described in the maxillary gland of certain fresh-water Ostracods (1925). It most probably agrees with the latter in being ectodermal in origin.

In *Estheria* the sphincter cells did not seem to be connected to the cuticle—they appeared simply as a triangle of three cells surrounding the duct. In *Chirocephalus*, when the antennal gland begins to degenerate, the sphincter cells break their connections with the ectoderm. It is probable then, that in *Estheria*, in the stage when the sphincter was observed, the connection to the cuticle had already broken down. In *Estheria* again the sphincter cells very soon merge into the end-sac walls. In the antennal glands of the Cypridæ that I have described (1925, p. 10), I could not distinguish separate sphincter cells, the fibrils merely occurred in cells forming part of the end-sac walls. There is thus a series starting with *Chirocephalus*, passing through *Estheria*, and finally the Cypridæ, in which can be seen the gradual incorporation of the ectodermal sphincter cells into the mesodermal walls of the end sac.

With the appearance of the maxillary gland the antennal gland begins to degenerate. It first of all breaks away dorsally from the ectoderm, the end sac as well as the sphincter cells breaking their connections. The end sac

then loses its cavity and remains as a solid mass of cytoplasm containing nuclei that are apparently degenerate. The duct cells lose their lumen but retain their large nuclei and become merged into the ectoderm surrounding the exit. From the similarity between this gland and the maxillary gland of the Cypridæ, the development of which I have described (1925, p. 13), I think the deduction is warranted that the duct cells are ectodermal in origin. If so, the primitive ectoderm cells, after growing inwards to form the duct, in the course of the degeneration of the gland, simply pass back to their place of origin. In the adult animal the remains of the duct cells can still be seen in sections as a glandular patch on the posterior face of the basal joint of the antennæ, and close against their inner face is a very faintly staining mass which is the remains of the end sac.

The development of the maxillary gland I have not followed in any detail. It shows no important difference from that of *Estheria*. As in the latter it develops from the ventral mass of mesoderm in connection with the first dorsal coelomic sac. The gland is entirely mesodermal in origin, there being no ectodermal invagination into the efferent duct. The cavity of the end sac appears very early, thus differing from *Estheria*. In a larva showing only six or seven trunk segments, indications of the end-sac cavity can be seen in the mesoderm mass although the primordia of the coils of gland are as yet undifferentiated.

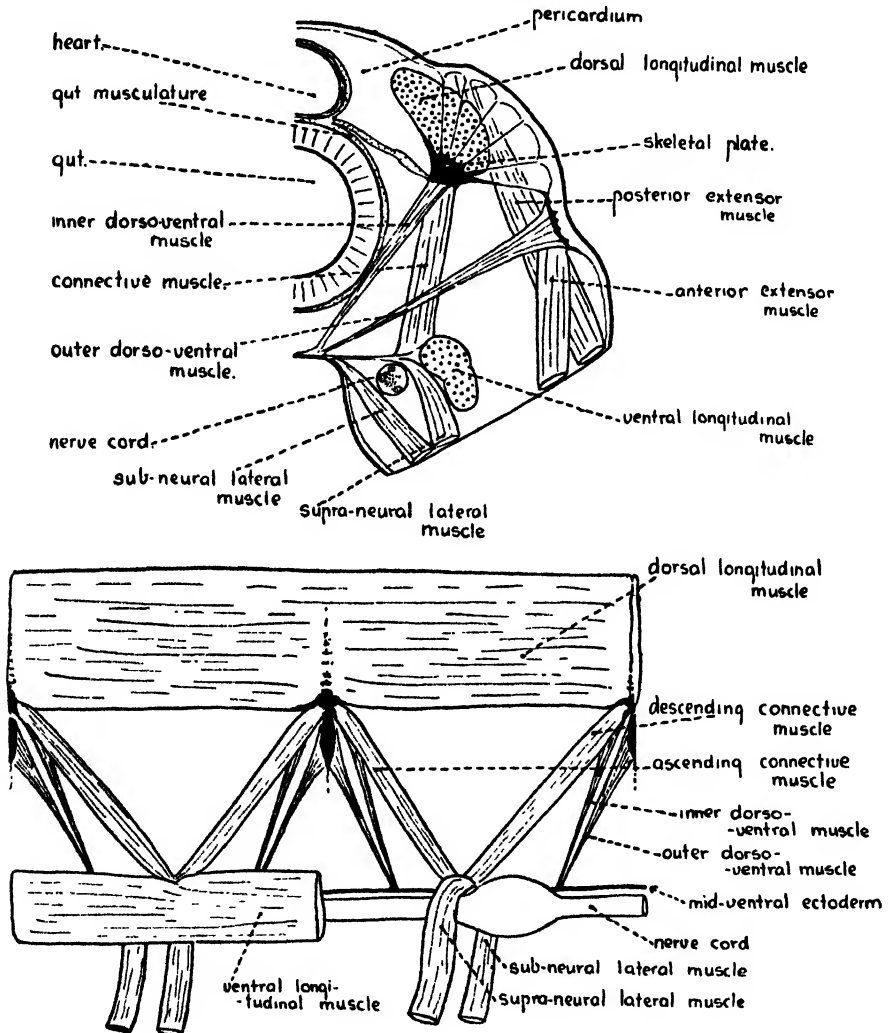
#### *The Musculature and Endoskeleton.*

The musculature of a typical trunk segment of *Chirocephalus* is very similar to that which I described in *Estheria* (1924, p. 407). All the muscles of the latter form are present but, in addition, there occur a series of "ascending and descending connective muscles." The relation of these to the other muscles can best be explained after a description of the development of the muscles that I have called in *Estheria* the anterior and posterior dorso-ventral muscles.

The development of these muscles can best be seen in a metanaupliar stage showing five or six rudimentary trunk limbs, and the fact that differentiation proceeds regularly from before backwards enables the successive developmental stages to be seen in successive segments. This is especially clear in a series of frontal sections. In such a specimen the limbs can be recognized externally as a series of ventro-lateral pouches diminishing in size posteriorly. Internally these pouches are delimited by a series of intersegmental ectodermal ridges. As the limbs develop the inner edges of the ridges become nipped off from the more lateral ectoderm so as to form continuous strings of cells running from the mid-ventral to the dorso-lateral regions of the body. These are the primordia of the inner series of dorso-ventral muscles (Pl. 22, fig. 4). This process can be seen very clearly in the frontal section shown in fig. 3 (Pl. 22). In the hinder less-developed

segments the ectodermal intersegmental ridges are barely discernible. In passing forwards they become more pronounced, and at the level marked with an asterisk the commencement of the separation of the inner edge can be seen, while in the next intersegmental plane this separation is complete.

TEXT-FIG. 3.



A diagram showing the typical trunk muscles when viewed from the front and from the side.

After the separation of these primordia and as the limbs continue to grow the ectodermal ridges are carried outwards and another string of cells is nipped off in the same manner as in the first series. These run similarly from the

mid-ventral line but end dorsally in the ectoderm just below the ends of the inner series. They form the primordia of the outer series of dorso-ventral muscles (Pl. 23. fig. 7).

At their ventral ends these columns of cells are very narrow, but dorsally they spread out into a fan in the transverse plane (Pl. 22. fig. 5). This spreading becomes much more pronounced at a later stage owing to the growth apart of the cells in this region. Very soon after their separation they become straightened out owing to the comparatively rapid growth of the trunk, and in this way each comes to form a tight stay between the ventral and dorso-lateral ectoderm. This can be seen by comparing fig. 4 (Pl. 22) which shows a dorso-ventral muscle very soon after its separation from the ectodermal ridge, with fig. 5 (Pl. 22) which is from the same specimen and depicts the same muscle in the next but one more anterior intersegmental plane. This process is very important, as it is in connection with this rigid system of stays that the other trunk muscles develop.

Continuous deeply-staining fibrils now appear in each column of cells, at first at the dorsal fan-like end, and later extending ventrally (Pl. 22. fig. 5). They begin from the outer surface of the superficial ectoderm cells, in contact with the cuticle, and the commencement of each is marked by a depression as if it were in a state of tension and were pulling on this surface. They run in between the surface nuclei, and at first a few run down the columns in an irregular manner. Later more fibrils extend down the columns and become grouped into a bundle on the inner sides, the nuclei arranging themselves in a row on the outer sides (Pl. 23. fig. 6). An important point at this stage is that the individual fibrils can be traced up to their dorsal termination each in a continuous curve. They do not bend discontinuously at an angle as they spread out dorsally to form the fan. From their later development it is clear that these fibrils correspond to what Humperdinck (1922, p. 645), among others, called "Tonofibrillen." The name "tendofibril" will be used here as being more suitable and as indicating simply a fibril in a state of tension.

At the level of the inner face of the surrounding ectoderm cells, where the tendofibrils commence to spread out into a fan, the latter now lose their staining capacity and the region becomes marked by an apparently homogeneous non-staining zone. This is the commencement of the formation of a rigid skeletal plate. At the same time, below this zone the bundle of tendofibrils develops signs of cross-striation, at first, simply deeply-staining zones alternating with zones in which the fibrils stain less intensely. Such a stage is shown in fig. 8 (Pl. 23). It will be seen from this that the more ventral portions of the fibrils, that may now be referred to as myofibrils, still form continuous curves with the more dorsal tendofibrils, as if there can be, as yet, no rigid structure in the non-staining zone. A marked difference is seen in the next stage shown in fig. 9 (Pl. 23). Here the myofibrils, which

are now much more pronounced, make sharp angles with the radiating system of tendofibrils, and undoubtedly at this stage a rigid skeletal structure has formed between the two.

As this tendinous plate is developed the cytoplasm immediately on its outer side disappears (Pl. 23. fig. 7), thus leaving it suspended to the superficial ectoderm by thin strands each containing one or more tendofibrils. In the adult these strands elongate considerably so that eventually the plate occupies a comparatively deep position in the trunk.

Below the plate the striation eventually becomes that of typical striped muscle, but this takes place comparatively very late. The primordia of all the other trunk and limb muscles are isolated after those of the dorso-ventral muscles, and yet they all develop their final striation before the latter.

At the ventral ends of the dorso-ventral muscles no skeletal plate is formed. The muscles simply narrow down to a thin tendon that runs directly to the cuticle in the mid-ventral line. Very soon after the isolation of the primordia the ventral ends split into two, apparently by a growth apart in an antero-posterior direction of two of the terminal cells. This division takes place before any fibrils have appeared in the columns, and when these do appear it can be seen in frontal sections that they are arranged in two bundles, an anterior and a posterior group, that merge into one dorsally. Of the two halves resulting from this splitting the anterior becomes the posterior dorso-ventral muscle of a segment and the posterior becomes the anterior dorso-ventral muscle of the segment behind, a fact that results from the intersegmental origin of the primordia.

The origin of the dorsal longitudinal muscles has been described in connection with the formation of the heart. The primordia of this muscle in each segment lie close against the ectoderm immediately above and between the dorsal ends of the dorso-ventral muscles. They develop continuous fibrils very early, about the same time as they appear in the dorso-ventral muscles, but these divide almost at once into typical striped muscle fibrils. The separate segmental portions soon join up to form one continuous muscle on each side, but, in addition, their lower edges join on to the skeletal plates of the dorso-ventral muscles.

The ventral longitudinal muscles are formed from ventral masses of mesoderm that lie over the primordia of the nerve ganglia, and in between the lower ends of the dorso-ventral muscles. They are shown in fig. 3 (Pl. 22). As development proceeds they pass laterally and then join up to form a continuous muscle on the outer sides of the nerve cords and dorso-ventral muscles. In passing outwards they retain connection with the mid-ventral ectoderm by a thin chitinous sheet which is a development of the basal membrane of the ectoderm of this region.

At the stage when myofibrils are appearing in the anterior end of the dorsal longitudinal muscle, strings of cells can be seen extending from

the primordium of the ventral longitudinal muscles, up the dorso-ventral muscles to the region where the skeletal plate will subsequently develop (Pl. 23. figs. 8 & 9). They appear to be entirely a development of the ventral longitudinal muscles and form the primordia of the series of muscles, unrepresented in *Estheria*, which I have termed the ascending and descending connective muscles. Their relation to the other muscles can be seen from text-fig. 3. The strings of cells extend up both the front and back of the dorso-ventral muscles. Those in front give rise to the ascending connectives and those behind to the descending. Dorsally attachment is made to the dorsal skeletal plates. Ventrally they attach close against the ventral longitudinal muscle, but actually to the thin chitinous sheet that connects the latter to the mid-ventral ectoderm. The ventral attachments are such that where a descending connective attaches, the succeeding ascending also attaches. In this way a complete zig-zag of connective muscles passes down the trunk between the dorsal and ventral longitudinal muscles.

The connective muscles do not occur in front of the first trunk segment. The ectodermal dorso-ventral muscles, however, can be traced in each segment up to the antennulary, with the doubtful exception of the maxillary segment. Their dorsal attachments in the naupliar region are as in the trunk, but the skeletal plates do not sink in but remain as thickened tendinous sheets continuous with the basement membrane of the surrounding ectoderm. The ventral attachments, however, are different. Those of the antennal segment attach not to the mid-ventral cuticle but to an endoskeletal plate overlying the stomodæum, while the posterior mandibular muscle attaches directly to the tendon joining the transverse mandibular muscles.

The chief interest in the development of the trunk musculature lies in the fact that a complete series of muscles are of purely ectodermal origin. But these are not the only muscles derived from that germ-layer,—the proctodæal dilators and some, at least, of the circular muscles of the proctodæum are also ectodermal. It is also probable, from a comparison of the adult œsophageal musculature with that of the proctodæum, that the œsophageal dilators are of a similar origin.

The development of the proctodæal dilators is very simple and can be seen very clearly in the nauplii and very early metanauplii. Certain ectodermal cells, at the posterior limit of the trunk, where the ectoderm turns in to form the proctodæum, elongate in a direction more or less transverse to the length of the animal. One end of the elongated cell remains in the outer ectoderm while the other passes in with the intucking ectoderm, so that the cell comes to span across the proctodæal space. Along the length of this cell fibrils appear almost at once (Pl. 23. fig. 10), which run continuously from the outer cuticle to the cuticle lining the proctodæum. These fibrils divide up into segments very early to give rise to the typical structure of a striped muscle-cell.



In the posterior part of the proctodæum its mid-dorsal and mid-ventral walls are fused with the outer ectoderm, so that the proctodæal space is divided into two lateral halves. In this region some of the circular muscles, if not all, are formed in the same way as the dilators. Ectoderm cells elongate in a dorso-ventral direction, and as the ectoderm invaginates retain one end in the mid-dorsal line and the other in the mid-ventral line, the attenuated cell-body in between lying close against the outer surface of the invaginating proctodæal epithelium (Pl. 23. fig. 10). In the resulting cells the myofibrils can be seen to end directly against the cuticle in the mid-dorsal and mid-ventral lines (Pl. 23. fig. 11).

An interesting point in connection with these proctodæal muscles is the early stage at which they develop their cross-striation. In a very early metanauplius this is complete, and in such a form the muscles can be seen to function. It is usually stated that for the contraction of striped muscle, a nerve stimulus is necessary, but it is difficult to see how a stimulus can reach the proctodæal musculature in a larva in which the post-naupliar region is in such an undifferentiated condition. In the zoæa of a crab these muscles can be seen similarly to function even after the complete severance of the abdomen. In this case no nervous system can be seen in the abdomen, and the existence of a definite nerve-track from the anterior ganglia to the proctodæum does not seem possible owing to the undifferentiated mass of tissue at the posterior limit of the thorax that intervenes between them.

The generally accepted view as to the origin of the musculature in Crustacea is that it is derived from the mesoderm. Suetblage (1905) and Moroff (1912), however, came to the conclusion that it was of ectodermal origin. The former, working on *Artemia*, describes the primordia of the limb muscles as being budded off from the overlying ectoderm. From his figures it is probable that the fixation of his material was not sufficiently good to enable the mesoderm clearly to be made out. The development of *Artemia* is without doubt very similar to that of *Chirocephalus*, and here the mesoderm cells, from which the main limb muscles are formed, can be distinguished very sharply at the earliest stages. Moroff, working on *Palæmon*, is not so definite. He merely states (1912, p. 561), referring to the primordia of the limb muscles, "Es macht mir den Eindruck, als ob sie aus dem Verband der übrigen Epithelkerne ausgetreten seien."

In the regenerating limb of the Crayfish Reed (1904) has observed the formation of muscles from the ectoderm, and Nusbaum (1902), although not working on Crustacea, states that in Enchytræids the regenerating muscles also arise from the ectoderm. In correspondence, Mr. Elmhirst of Millport tells me that, in regenerating papillæ of the Hermit Crab, the muscles are similarly formed. But this question involves a consideration of the potentialities of the germ-layers, a problem quite apart from that of their homologies. The germ-layer origin of organs during regeneration, and

indeed in asexual reproduction generally, often differs from the normal origin, as, for example, in the well-known cases of certain Tunicates and Syllids.

In *Chirocephalus* there can be no doubt that certain muscles are mesodermal, while others are ectodermal in origin. The latter are of interest, not so much because they are ectodermal, for ectodermal muscles occur in certain Annelids (Staff, 1910, p. 251) and might be expected in forms evolved from the Annelids, but because of their method of origin. In the two cases described in this paper, the muscles are formed in one from an infolding of ectoderm, while in the other they are formed in connection with an intucking of ectoderm. If these methods are of general occurrence, and I see no reason to suppose that *Chirocephalus* is unique in this respect, it follows that wherever an intucking of ectoderm occurs, such as, for instance, in the gastric mill of certain Crustacea, or an infolding, such as at the joints of a Crustacean limb, ectodermal muscles can arise.

In a series of transverse sections of *Anaspides* that I possess, there is a dilator muscle of the masticatory stomach which, I am convinced, must be of ectodermal origin. Its attachments agree closely with those of the proctodæal dilators of *Chirocephalus* and, as I shall explain further on, the method of attachment can be used as an indication of ectodermal muscles. Again, the primitive muscles described by Humpferdinck (1922, p. 647) occurring at the joints of the limbs of *Polyphemus* and serving as trochleas for the limb musculature, are ectodermal and are comparable with the dorso-ventral muscles of *Chirocephalus*.

It has been suggested to me that these ectodermal muscles are really structures derived from a mesectoderm or larval mesenchyme, such as occurs in an Annelid trochophore. I do not think that this can be so. Mesectoderm is a very definite tissue. It has a definite mode of formation and it occurs in definite regions. In Annelids it occurs in the trochophore but not, as far as I am aware, in the post-trochophoral growing region, and this region I take as corresponding to the post-mandibular region of the nauplius. In both post-trochophoral and post-naupliar regions there is a mass of mesoderm that, at one stage, occupies the whole space between endoderm and ectoderm and in which the coelomic cavities are formed later, but in the former there is no mesectoderm and I see no reason to assume that it occurs in the latter. It may occur in the naupliar region, in fact Urbanowicz (1884, p. 616) has described it as occurring in the nauplius of *Cyclops*, and here it may be the homologue of the mesectoderm of the trochophore, but there is no evidence that it is formed also in the post-naupliar region. It may be maintained, however, that in the Crustacea it is a new development in the post-naupliar region, serially homologous with true mesectoderm of the anterior

segments, but the mode of formation of the ectodermal muscles is so characteristic and is so different from that of larval mesenchyme that I think this is highly improbable. The latter is always formed by a budding off inwards of ectodermal cells which, in later organogeny, group themselves together, whereas the Crustacean ectodermal muscles are formed by the stretching out of ectoderm cells across the blastocoele.

The dorso-ventral muscles, once they are formed, cannot be distinguished from the mesodermal muscles. They end dorsally against an internal tendinous plate and ventrally they narrow down to a thin tendinous strand. But the proctodæal muscles are different in that their myofibrils end directly against the cuticle. This difference, I think, accounts for the divergence of opinion that has always existed as to the mode of attachment of Arthropodan muscles. Many authors, of which a complete list can be found in Grobben's paper (1911), hold that the muscles are always attached to the basement membrane of the ectoderm, that is, indirectly to the cuticle. Others, however, maintain that the muscles are attached directly to the cuticle, the muscle cells passing in between the ectodermal cells for this purpose. A review of the papers of these latter workers shows that those muscle attachments that they illustrate as showing the direct method of attachment to the cuticle are practically all taken from proctodæal musculature or from muscles which it is logical to infer are formed in a similar manner. Thus Frenzel (1885, p. 148) in *Scyllarus* and Yonge (1924, p. 82) in *Nephrops* describe direct attachment in proctodæal dilators. Ide (1892) figures the same state of affairs in certain Malacostraca for the dilators of the œsophagus and gastric mill. In the proctodæum he describes (p. 174) circular muscles in addition to the dilator muscles ending directly against the cuticle of the mid-ventral line, just as I have described for *Chirocephalus*. I thus think it probable that, wherever the myofibrils of a muscle pass in between the ectoderm cells and end directly against the cuticle, the muscle is of ectodermal origin.

The foregoing account is in no way complete but from it, I think, certain general conclusions as to Crustacean Musculature can be deduced. The musculature consists of two types, the mesodermal and the ectodermal. The former undoubtedly represents the mesodermal musculature of the Annelida. The ectodermal muscles are, I think, the representatives of internal supporting structures which were primitively formed from the ectoderm simply for the support of the body or internal organs and which have subsequently taken on a muscular function. Originally, probably, they evolved *pari passu* with the rigid exoskeleton to compensate for the disappearance of the circular musculature, or they may even be representatives of the latter. Then, as the exoskeleton became more

and more efficient such support became unnecessary and they assumed, or reverted to, a muscular function. An interesting case illustrating this process is the formation of the sphincter of the maxillary gland of certain Cypridæ. I have shown (1925, p. 13) that this structure arises from the ectoderm, and is, to begin with, merely a supporting structure for the end sac. Only later does it become the sphincter controlling the entrance of the duct into the end sac. But here the process does not go so far as the development of striped muscle—it stops short at a stage more comparable with unstriped muscle.

The fibrils that appear first in the ectodermal muscle primordia, I have called tendofibrils simply because, from the mode of formation of the muscle and from their appearance in sections, they are evidently on the stretch. In fact, a certain degree of tension must be incidental to any supporting structure. The fact that later they divide up into typical myofibrils is, I think, most probably conditioned by this state of tension. There is the analogous case of the experimental transformation of unstriped into striped muscle by increasing the tension to which it is normally subjected (Carey, 1921, p. 341).

The origin of the endoskeleton is another subject about which much controversial matter has been published. *Chirocephalus* is not a form in which its development as a whole could be worked out in detail owing to the difficulty of tracing the embryonic stages, but it does illustrate some interesting points. That part of the endoskeleton can be purely ectodermal in origin I have shown in connection with the development of the dorso-ventral musculature. A considerable part is, however, developed from the basal membrane of the ectoderm.

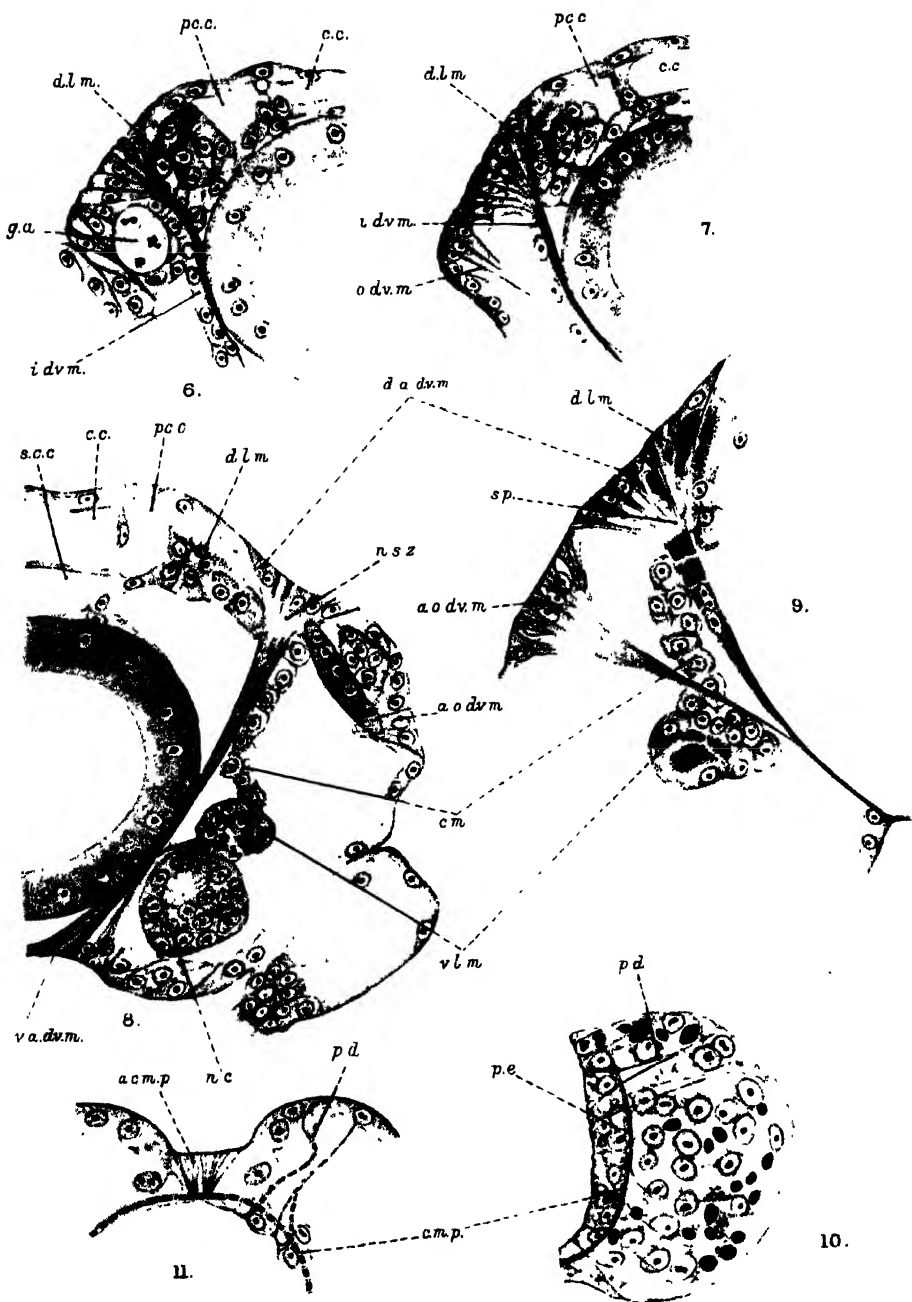
I cannot agree with Humpferdinck's statement (1922, p. 652) that the endoskeleton is non-cellular and is merely a cell product. In certain regions, for instance in the tendinous skeletal plate joining the mandibular transverse muscles, there can be seen included in it very large nuclei. This tendon arises as the basement membrane of the ectoderm in the mid-ventral mandibular region, and the large nuclei arise from cells that can be seen closely overlying this membrane in the earliest nauplius. There is another tendinous sheet overlying the stomodæum and underlying the gut to which the inner dilators of the œsophagus are attached, and this also contains very large nuclei. I have not been able to follow the development of this plate, as it is already formed in the nauplius, but I feel convinced that it also represents the basal membrane of the dorsal stomodæal ectoderm which becomes lifted up from the stomodæal cells. Probably also, as it is lifted up certain cells retain connection with it and also with the stomodæal cuticle, and these become the dorsal stomodæal dilators. If so, this represents yet another type of ectodermal musculature.



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CHIROCEPHALUS DIAPHANUS





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## EXPLANATION OF THE PLATES.

*List of Abbreviations used.*

- a.c.m.p.* = dorsal attachment of circular muscles of proctodæum.
- a.o.dv.m.* = dorsal attachment of outer dorso-ventral muscle.
- a.s.e.* = attachment of sphincter of antennal gland to ectoderm.
- c.c.* = cardiac cavity.
- c.m.* = primordium of connective muscles.
- c.m.p.* = circular muscles of proctodæum.
- c.s.* = coelomic sac.
- d.a.dv.m.* = dorsal attachment of inner dorso-ventral muscle.
- d.l.m.* = dorsal longitudinal muscle.
- e.d.* = efferent duct of antennal gland.
- e.e.s.* = entrance of duct into end sac of antennal gland.
- e.s.* = end sac of antennal gland.
- g.a.* = primordium of gonad.

- g.m.* = circular muscle of gut.  
*i.d.v.m.* = inner dorso-ventral muscle.  
*i.e.r.* = inner-segmental ectodermal ridge.  
*n.c.* = nerve cord.  
*n.s.z.* = non-staining zone on primordium of dorso-ventral muscle.  
*o.d.v.m.* = outer dorso-ventral muscle.  
*p.d.* = dilator muscles of proctodæum.  
*p.e.* = proctodæal epithelium.  
*pc.c.* = pericardial cavity.  
*s.c.* = sphincter cell of antennal gland.  
*s.c.c.* = sub-cardiac cavity.  
*s.p.* = skeletal plate on primordium of dorso-ventral muscle.  
*v.a.d.v.m.* = ventral attachment of dorso-ventral muscles.  
*v.l.m.* = ventral longitudinal muscles.

## PLATE 22.

- Fig. 1. A horizontal (frontal) section of the post-mandibular region of a larva about 0.5 mm. in length through the level of the coelomic sacs.  
 Fig. 2. A horizontal section through the junction of end sac and efferent duct of the antennal gland, showing the sphincter attached directly to the cuticle.  
 Figs. 3-9 illustrate the formation of the ectodermal dorso-ventral muscles.  
 Fig. 3. A horizontal section through a 0.5 mm. larva, showing the formation of the trunk limbs and the separation of the primordia of the dorso-ventral muscles from the intersegmental ectodermal ridges.  
 Figs. 4-9 illustrate the progressive development of fibrils in the primordia of the muscles and their subsequent differentiation into dorsal tendofibrils and ventral myofibrils.  
 Fig. 4. A transverse section through the intersegmental region, showing the separation of the primordium of the inner dorso-ventral muscle from the intersegmental ectodermal ridge.

## PLATE 23.

- Fig. 5. A transverse section showing the development of fibrils in the upper portion of the primordium and their attachment to the cuticle.  
 Fig. 6. A transverse section showing the fibrils gathered together in a bundle and spreading out dorsally into a fan.  
 Fig. 7. A transverse section showing the breaking down of the cytoplasm of the most dorsal cells of the primordium.  
 Fig. 8. A transverse section showing the appearance of the non-staining zone and the appearance ventral to this of the myofibrils.  
 Fig. 9. A transverse section showing, in the inner dorso-ventral muscle, the skeletal plate and the complete formation of striped muscle ventral to it. The outer dorso-ventral muscle in this figure is at the same stage as that shown in fig. 7.  
 Fig. 10. A transverse section through one side of the posterior limit of a nauplius, showing the ectodermal origin of the proctodæal muscles.  
 Fig. 11. A transverse section through the dorsal part of the proctodæum of a larva about 0.5 mm. in length, showing the median attachments of the circular muscles and the cuticular attachments of the dilators.

All the figures are camera lucida drawings at a magnification of 1050. Figures 9, 10, and 11 are drawn from Mr. Speyer's preparations, the remainder are from my own slides.

Ciliary Feeding Mechanisms in the Thecosomatous Pteropods. By C. M. YONGE, B.Sc., Ph.D., Temporary Assistant Naturalist at the Plymouth Laboratory. (From the Station Zoologique Russe, Villefranche-sur-Mer.) (Communicated by Dr. H. G. CANNON, F.L.S.)

(With 5 Text-figures.)

[Read 4th November, 1926.]

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#### 1. INTRODUCTION.

ALTHOUGH it has long been known, as a result of the investigations of Gegenbaur (1855), Roas (1885), Pelseneer (1888), Tesch (1904, 1913), and, above all, Meisenheimer (1905) that the Thecosomatous Pteropods feed by means of ciliary currents, yet the actual process of feeding has never been described and figured in detail, largely, I think, because the majority of the observations hitherto have been made on preserved material. During a short visit to the Station Zoologique Russe at Villefranche in February 1926, I took the opportunity presented by the great numbers of Pteropods then occurring in the plankton, of tracing out the exact course of the ciliary currents in four selected species. I also carried out a series of feeding experiments the results of which will be described in a later paper. No observations were made on the feeding processes of the Gymnosomatous Pteropods, which do not possess ciliary feeding mechanisms.

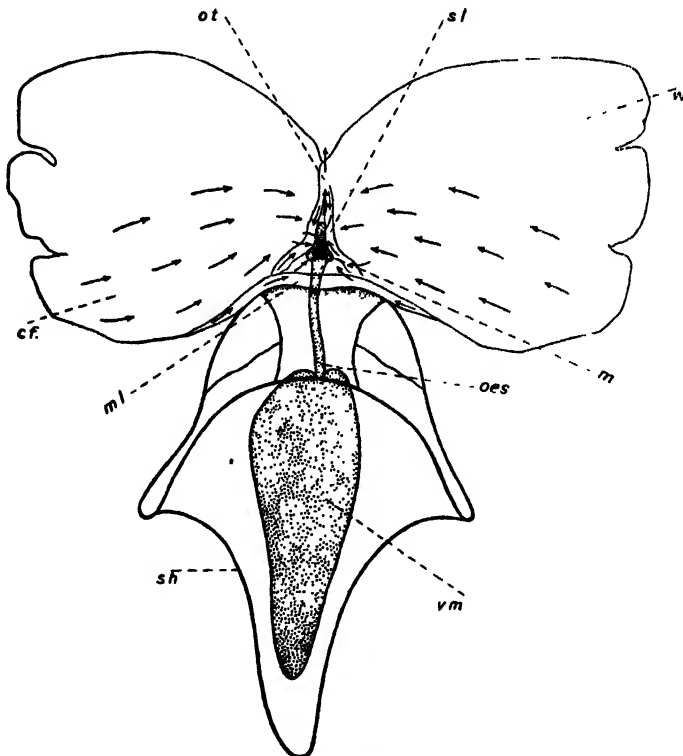
I wish to express my gratitude to Professor Davidoff and Dr. G. Trégouboff and their Assistants of the Laboratory at Villefranche for their great kindness and help, and also to the Carnegie Trust of the Universities of Scotland for providing me with a grant of money to defray the expenses of my visit to Villefranche.

## 2. CILIARY MECHANISMS.

The four species chosen for examination were: *Cavolinia inflexa*, *Creseis acicula*, *Cymbulia peronii*, and *Gleba (Tiedemannia) cordata*. They were selected as showing different stages in the development of the ciliary mechanisms. Although the genus *Creseis* is considered by the systematists to be more primitive than *Cavolinia*, yet in the disposition of the ciliary mechanisms, which are very similar in the two genera, *Creseis* appears the more specialized, and accordingly *Cavolinia* is here described first.

The course of the ciliary currents was followed under the low powers of the microscope by placing the animals in shallow glass dishes containing sea-water, and adding drops of suspensions in sea-water of carmine, Indian ink, or fine carborundum powder.

FIG. 1.

*Cavolinia inflexa*.

Whole animal from ventral aspect, showing ciliary currents leading to the mouth.  $\times 7$ .

a. *Cavolinia inflexa*. (Fig. 1.)

The ciliary mechanism in this species is the simplest and least specialized of the four species here described. There is a ciliated field (Wimperfeld)

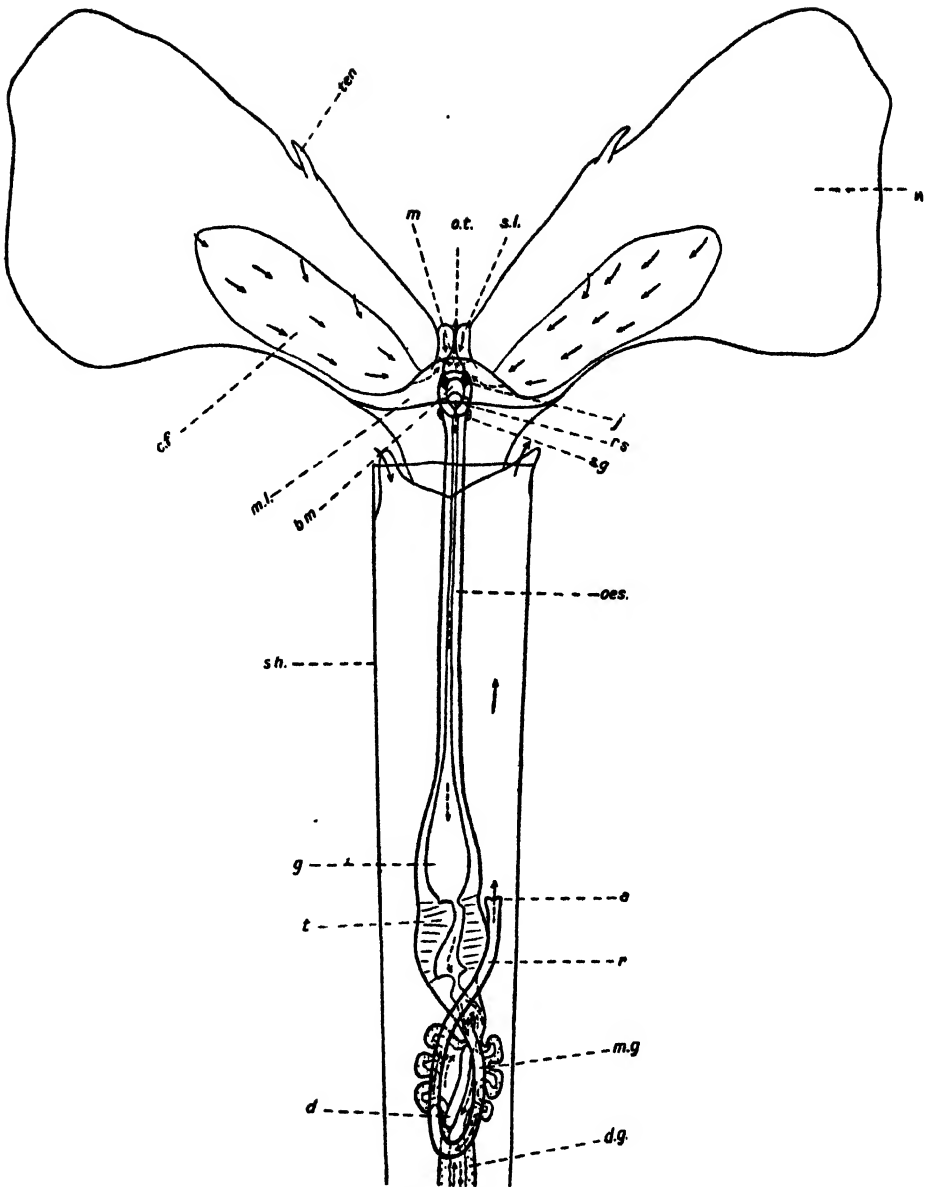
attached to the posterior margin of each of the wings, and approximately equal to them in size. There are numerous unicellular mucus glands between the ciliated cells. The beating of the cilia drives particles towards the mouth, which is enclosed in a triangle formed by three ridges representing, as Meisenheimer has shown, the unpaired middle lobe (*m.l.*) and two side lobes (*s.l.*) of the foot. Meisenheimer has further shown that the ciliated field is to be regarded as a lateral extension of the middle lobe of the foot; its epithelium is quite distinct from that of the wings, while, in common with the middle and side lobes, it is innervated from the pedal ganglion. The three ridges are all ciliated, and food particles pass on from them to the mouth, as shown by the direction of the arrows in fig. 1. They are contractile, and may be drawn together so that the mouth is covered and the particles gather into a ball at the summit of the contracted ridges, being later shaken off by the flapping of the wings. Even when they are not contracted, however, not all the particles necessarily pass into the mouth. If too much material is brought by the ciliary currents, it accumulates about the mouth and is then carried off by a tract of cilia (*o.t.*) which lies above the mouth in the groove between the side lobes. Particles which are passed on to the mouth do not proceed without interruption into the œsophagus, but are admitted first into the buccal mass, which contains a pair of jaws, a small radula and salivary glands, and are taken into the œsophagus by a series of definite swallowing actions.

b. *Creseis acicula*. (Fig. 2.)

This species, while resembling *Carolinia* in all essentials, possesses a ciliary feeding mechanism which is somewhat more restricted in area. Since the body is transparent, it is possible to follow the course of the food, not only on its way to the mouth, but also throughout the entire length of the gut. Food is collected on clearly defined ciliated fields (*c.f.*) which lie superimposed upon the wings and are relatively much smaller than in *Carolinia*. They are more obviously extensions of the middle lobe on the foot than in *Carolinia*, as is shown clearly in fig. 2. The middle lobe is large and obscures the mouth when the animal is laid with the ventral side upwards. Food is passed from the ciliated fields to the mouth, which is bounded by the two side lobes. The three lobes do not contract together as in *Carolinia*, but there is a well-defined outgoing tract in the same position as in that species for the rejection of surplus matter. Any abnormal surplus is removed by a violent flapping of the wings.

From the mouth the food passes into the globular buccal mass (*b.m.*), into which opens a pair of small salivary glands (*s.g.*), and which is furnished above with a pair of chitinous jaws (*j.*) and below, and more ventrally, with a radula sac (*r.s.*) containing a small radula which is made up of about ten transverse rows each consisting of three teeth (Meisenheimer). Food

FIG. 2.

*Cressia acicula.*

Anterior half of body from ventral aspect, showing ciliary currents leading to the mouth and the course of the food through the alimentary canal. Only the alimentary organs are shown.  $\times 20$ .

proceeds into the œsophagus (*oes.*) as a result of a definite swallowing act, and there comes under the action of the cilia with which all parts of the gut (with the exception of the gizzard) are lined. It streams down the long œsophagus into the so-called stomach, a pear-shaped organ which, as Pelsener (1888) has observed, is in reality, in this as in all other Thecosomata, "a masticatory gizzard with muscular walls, and exhibits four large symmetrical plates, a fifth posterior plate, and generally eight small anterior plates." The teeth (*t.*) are well developed, but since the food particles are invariably minute as a result of the mode of collection the mastication which they undergo appears quite unnecessary, and the invariable presence of these gastric teeth in the Thecosomata may be attributed to their descent from Tectibranchs such as *Scaphander*, with which, according to the classification proposed by Pelsener (1888, 1906), they are closely allied. *Scaphander* swallows its prey—which usually consists of small bivalves—whole, "to be broken up by the calcareous plates of its powerful gizzard" (Hunt (1925)).

Behind the gizzard is a chamber into which open side by side the mid-gut and the digestive gland ("liver"); and into either of these openings food may pass. The digestive gland in *Creseis* is greatly modified owing to the needle-like shape of the body. It is slightly lobed immediately behind the gizzard, and it extends to the extreme tip of the long body as a single straight tube. It is usually yellow or brown in colour and composed of a single layer of large cells, the whole organ being so transparent that food particles can be seen within it being passed rapidly up and down as a result of rhythmical peristaltic movements. Although difficult to observe with certainty, cilia are probably present, but they are certainly not so regularly arranged or so numerous as in the remainder of the gut. When the digestive gland of a freshly caught animal is examined, the contained food appears as greenish-brown masses, obviously of a predominantly vegetable nature. It is known that in many Gastropods food particles pass into the cavity of the digestive gland where they are ingested and digested intracellularly, by absorptive cells (*e. g.*, the observations of Enriques (1901) on *Aplysia*, of von Bruel (1904) on *Caliphylla*, of Jordan (1918) on *Helix*, etc.). I do not intend to discuss the question of absorption in this paper, but observations on the movement of food in the gut of *Creseis* showed that particles are passed into the digestive gland, presented to the large—presumably ingesting—surface and then, if not taken in, passed back to the opening and into the mid-gut.

Opening into the alimentary canal about the junction of the digestive gland and the posterior end of the gizzard there is a small finger-shaped diverticulum (*d.*), which is ciliated but into which food does not pass. The nature and function of this organ will be discussed later. Particles which enter the mid-gut, either directly from the gizzard or by way of the digestive gland, pass rapidly to the exterior, coming under the combined influence of

ciliary and peristaltic action. The mid-gut and rectum form a twisted loop so that the anus (*a.*) is situated at the left side of the stomach and points anteriorly. The faeces are discharged into the mantle cavity where, under the influence of the cilia which maintain a constant stream of water in the cavity, they are carried away (see the direction of the arrows in fig. 2).

An attempt was made to obtain some indication of the pH in the gut of *Creseis* by placing living animals in sea-water lightly coloured with neutral red or brom thymol blue. No clear results were obtained with the former, but with brom thymol blue the oesophagus, gizzard and digestive gland all coloured yellow (pH probably about 6.0), and the latter part of the mid-gut and the rectum deep blue (pH between 7.5 and 8.0). This agrees very closely with the results obtained (Yonge (1925)) for *Aplysia*, a benthic Tectibranch, in which the fore- and mid-gut are acid having a pH between 5.8 and 6.8, and the rectum is alkaline having a pH of 8.3.

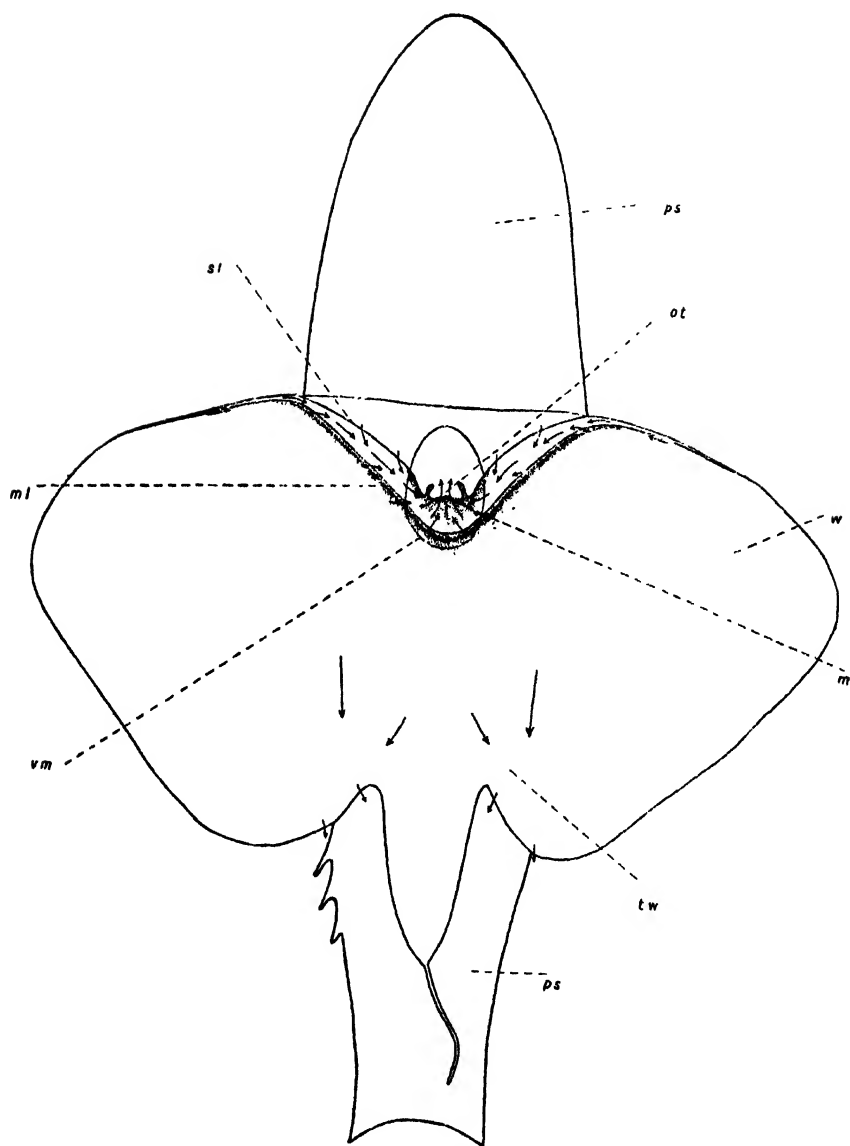
c. *Cymbulia peronii*. (Fig. 3.)

The ciliary mechanism is here greatly reduced, being formed exclusively by the middle and side lobes of the foot with no ciliated field extending from the former. The mouth (*m.*) lies in the middle line while on either side of it there extends a ciliated groove, the raised sides of which represent the lobes of the foot, the unpaired middle lobe forming the posterior side, and the two side lobes the anterior side. The grooves begin midway along the anterior margin of the wings as narrow ciliated tracts which widen and become raised up laterally as the mouth is approached. Particles which fall upon them are conducted to the bottom of the groove, where they come under the influence of a strong ciliary current leading straight to the mouth. This lies at the bottom of a funnel-shaped depression, the walls of which (like the alimentary tract within) are deeply pigmented. Food streams down into the mouth by way of the ciliary currents which line this depression, but whether it passes directly into the oesophagus or has to be swallowed it is impossible to say. There is a buccal mass in *Cymbulia* possessing jaws, radula, and salivary glands, but all of these are much less developed than in the two species already described.

Any excess of food is removed as before by an outgoing tract of cilia (*o.t.*) situated on the lobe which overlies the mouth anteriorly, separating the two side lobes of the foot, *i. e.*, occupying the same relative position as in *Cavolinia* and *Creseis*. Particles caught in this tract are led away from the mouth, rolled into a ball and, when large enough, shaken free. The greater part of the surface of the wings is, as usual, not ciliated, the surface being kept clean by continual flapping. There are, however, tracts of slowly moving cilia (*t.w.*) on either side of the middle line (*i. e.*, where flapping will have no effect) which lead foreign particles to the posterior margin of the wings, where cilia occur along the two short stretches on each side as delimited by the two sets of arrows shown in fig. 3.



FIG. 3.



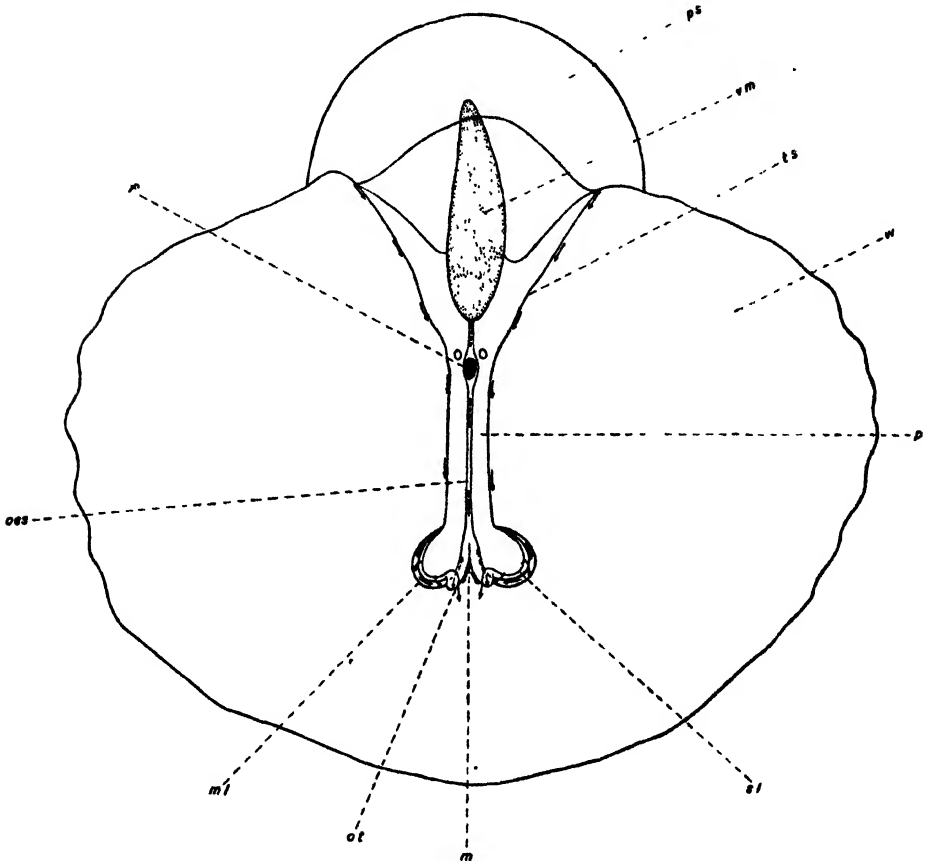
*Cymbulia peronii.*

Whole animal from oral aspect, showing ciliary currents leading to mouth and on the wings.  $\times 2\frac{1}{2}$ .

d. *Gleba cordata*. (Figs. 4 & 5.)

In *Gleba*, although conditions are essentially the same as in *Cymbulia*, the rudimentary triangular proboscis developed in the latter has become drawn out into a long proboscis (fig. 4), attached by a broad base and extending backwards parallel to the surface of the wings. This is flattened from above downwards and has a pair of lateral rounded lobes at the tip.

FIG. 4.

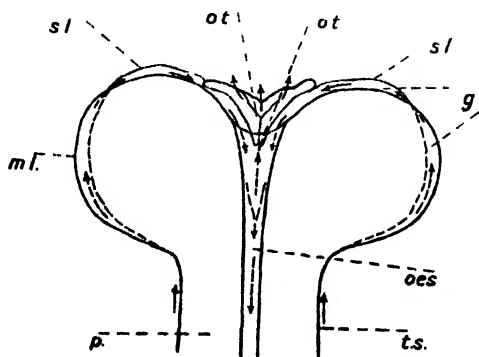
*Gleba cordata*.

Whole animal from oral aspect, showing ciliary currents leading up the side of the proboscis to the mouth, and the course of food down the oesophagus.  $\times 2\frac{1}{2}$ .

Narrow ciliary tracts (*t.s.*) begin where the edges of the broad base are attached to the wings and run, one up either side of the proboscis, leading into grooves which bound the outer margin of the terminal lobes. As in *Cymbulia*, these grooves are formed by the lobes of the foot, the two side

lobes (*s.l.*, fig. 5) forming the upper ridge, and the unpaired middle lobe (*m.l.*) the lower ridge. The mouth (*m.*) lies in a depression at the tip, and in the middle line, of the proboscis. Particles enter it from the grooves and then pass without interruption into the œsophagus, which can easily be seen through the transparent tissue of the proboscis. *There is no buccal mass, and hence no jaws, radula or salivary glands.* Material passes down the œsophagus under the combined influence of cilia and peristalsis, the particles often massing together into balls which extend the walls of the œsophagus (see *f.* in fig. 4). From the œsophagus, it proceeds to the gizzard and remainder of the alimentary canal which lie within the visceral mass (*v.m.*).

FIG. 5.

*Gleba cordata.*

Tip of proboscis, under surface.  $\times 6$ . *g.* Groove formed by middle and side lobes of foot; *m.l.* middle lobe of foot; *ot.* outgoing ciliated tracts on triangular area between side lobes; *oes.* œsophagus; *p.* proboscis; *s.l.* side lobes of foot; *t.s.* ciliated tract on side of proboscis.

The outgoing tracts for the removal of surplus matter are situated, as in the preceding species, on the lobe which lies between the side lobes of the foot. This can be seen in fig. 5, which represents the under surface of the proboscis. The middle lobe dips in the middle line exposing the triangular area lying between the side lobes. Particles pass down the grooves into the mouth, the two streams not uniting until they have passed a little way down the œsophagus (as shown by the union of the dotted arrows in the figure). The grooves are very narrow at the entrance to the mouth, so that if any large quantity of material passes along them it will overflow on to the triangular area, and so come under the influence of the outgoing tracts and be carried away. All rejected matter is rolled into a ball in the region between the two arrows at the tip of the proboscis in fig. 4, and finally shaken off. No cilia can be distinguished on any part of the wings in *Gleba*.

## 3. DISCUSSION.

The species examined show four stages in the adaptation of the Thecosomatus Pteropods to ciliary feeding. In each case the ciliary feeding mechanism is more localized and more efficient—because it is more compact and interferes less with the movement of the wings—than in the one preceding. This is brought about by the increased specialization of the middle and side lobes of the foot, out of which the ciliary mechanisms are in all cases formed. At the same time, the buccal mass and its associated structures, radula, upper jaws and salivary glands, which the Thecosomata have inherited from their benthic, and probably carnivorous, ancestors, gradually diminish, being represented by slight vestiges, of doubtful functional value, in *Cymbulia*, and being entirely absent in *Gleba* (and also in the allied genus, *Corolla* (*Cymbuliopsis*) as noted by Pelseneer (1888) and later investigators). The gizzard, probably another structure handed down from carnivorous ancestors and clearly of little use to an animal which feeds by ciliary mechanisms, is retained throughout.

A further and most interesting point is the presence of a blind appendage opening into the stomach at or near the opening of the digestive gland, and shown in the figure of *Creseis* (it was originally described in this genus by Gegenbaur). Meisenheimer states that a similar organ is present in all the Thecosomata, and that it is lined by a ciliated epithelium and contains a hyaline, structureless secretion which completely fills the hinder portion of the sac but decreases in circumference as it approaches the opening, beyond which, however, it may project. The diverticulum is too small for the contained secretion to be large enough to be seen except in sections, but in Meisenheimer's figures it bears a close resemblance to the crystalline style of the Lamellibranchs and primitive Gastropods. Meisenheimer has noted this resemblance and, discussing the probable function, states: "Seiner physiologischen Function nach hat dieser Blindsack, der nach Johannes Müller peristaltische Bewegungen ausführen soll, unzweifelhaft eine Rolle bei der Verdauung zu spielen, dafür spricht schon der auffallende Verbrauch seines Sekretes nach der Mündung hin . . . . . Ob diese Function in der Erzeugung eines besonderen verdauenden Sekretes besteht, oder ob auch hier das Sekret dazu dient, Fremdkörper und unverdauliche Hartteile der Nahrungsorganismen mit einer Hülle zum Schutze der zarten Darmwände zu umgeben, wie man es neuerdings für die Lamellibranchiaten angenommen hat, ist wohl schwer zu entscheiden." He rejects the older theory that it represents a bile secretion. The presence of a style—which contains an amylolytic enzyme and serves to whirl round food particles in the stomach (for review of recent work on the subject see Nelson (1925))—is always associated with a predominantly vegetable diet and, except in certain of the Gastropods, with ciliary feeding mechanisms (*e. g.*, in all the Lamellibranchs and in such Gastropods as *Crepidula* in which it is better developed than in

any other members of that class ; see Orton (1912) and Mackintosh (1925)). It is very striking that a similar structure should have arisen in the only group among the higher Gastropods which has developed ciliary feeding mechanisms and is to a large extent vegetarian. Boas has given an account of the stomach contents of the Thecosomata. In species from the warmer seas, he found *Globigerina* and other Foraminifera and also Radiolarians ; in those from the colder seas many Dinoflagellates, while in both he found Diatoms, Coccospheres and Tintinnids.

In the Gymnosomatous Pteropods, which are carnivorous—their food consisting, according to Massy (1917), largely of Thecosomata—and do not possess ciliary feeding mechanisms, there is no development of a blind sac, while radula, jaws and salivary glands (all associated with a carnivorous diet) are retained throughout. In the Thecosomata, as in the Lamellibranchs, the secretion of the blind sac may quite possibly contain an amylolytic enzyme for the extracellular digestion of the starch present in the vegetable food ; the older theory that it serves to coat hard particles has been abandoned as a result of recent work. The Mollusca are a very homogeneous phylum, and its members tend to produce similar structures in response to similar stimuli. The peculiar nature and form of the style are probably to be attributed, as I have already pointed out (1923), to the universal presence of mucus glands and cilia in the alimentary tract of the Mollusca (with the exception of the Cephalopoda), the former assisting in the formation of the substance of the secretion and the latter rolling it into shape.

#### 4. SUMMARY.

1. The ciliary feeding mechanisms of four species of Thecosomatous Pteropods, *Cavolinia inflexa*, *Creseis acicula*, *Cymbula peronii*, and *Gleba cordata*, have been studied.

2. The ciliary mechanism is in all cases formed by the unpaired middle lobe, and the two side lobes, of the foot, with the addition of tracts leading to them in the case of *Gleba* ; all food particles are conducted to the mouth.

3. There is a progressive reduction in the area occupied by the ciliary mechanism in the four species examined. In *Cavolinia* and *Creseis* the middle lobe is extended as a ciliated field, in *Cymbulia* the ciliary mechanism is composed of grooves leading to the mouth, one from the anterior margin of each of the wings, while in *Gleba* the mouth lies at the end of a proboscis, up the sides of which lead ciliated tracts, the grooves formed out of the lobes of the foot being confined to the rounded margin near the tip of the proboscis.

4. In all cases there is an outgoing tract of cilia for the rejection of surplus food situated on the small lobe which overhangs the mouth anteriorly and lies between the side lobes of the foot.

5. The restriction in area and increased specialization of the ciliary mechanisms is accompanied by a diminution and final disappearance (in *Gleba*) of the buccal mass and its associated structures, jaws, radula and salivary glands.

6. The course of the food through the alimentary canal has been followed in *Creseis*. The food, apparently mainly vegetable, is passed through by ciliary and peristaltic activity, being triturated in the gizzard and passed into the cavity of the digestive gland before being rejected by way of the mid-gut and rectum.

7. As a result of *intra vitam* staining with brom thymol blue in *Creseis*, the oesophagus, gizzard and digestive gland show a pH of about 6.0 and the latter part of the mid-gut and the rectum one of between 7.5 and 8.0.

8. A ciliated diverticulum is present in all species and opens about the junction of the digestive gland and gizzard. It contains a hyaline secretion strongly reminiscent of the crystalline style of the Lamellibranchs and certain Gastropods. It is suggested that in the Thecosomata, as in those animals, the style-like secretion may be correlated with the presence of ciliary feeding mechanisms which collect food principally of a vegetable nature, and may contain an amylolytic enzyme for the extracellular digestion of starch.

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## 6. REFERENCE LETTERING.

<i>a.</i> anus.	<i>p.</i> proboscis.
<i>b.m.</i> buccal mass.	<i>ps.</i> pseudoconch.
<i>c.f.</i> ciliated field.	<i>r.</i> rectum.
<i>d.</i> diverticulum.	<i>r.s.</i> radula sac.
<i>d.g.</i> digestive gland.	<i>s.g.</i> salivary glands.
<i>f.</i> food mass.	<i>s.l.</i> side lobes of foot.
<i>g.</i> gizzard.	<i>sh.</i> shell.
<i>j.</i> jaws.	<i>t.</i> tooth.
<i>m.</i> mouth.	<i>t.s.</i> ciliated tract on side of proboscis.
<i>m.g.</i> mid-gut.	<i>t.w.</i> ciliated tract on wings.
<i>m.l.</i> middle lobe of foot.	<i>ten.</i> tentacle.
<i>o.t.</i> outgoing ciliated tracts.	<i>v.m.</i> visceral mass.
<i>oes.</i> oesophagus.	<i>w.</i> wing.





On the Nuptial Callosities of Frogs and Toads from the Lamarckian point of view. By J. T. CUNNINGHAM, M.A., A.L.S.

(PLATE 24.)

[Read 8th May, 1926.]

IN the Common Frog, *Rana temporaria*, the nuptial pads or callosities in the male are thickenings of the horny epidermis on the inner sides of the fore-feet or "hands." The surface of the pad is raised into pointed papillæ, and the horny outer layer is of a deep black colour, contrasting with the neighbouring skin. The pad is divided by grooves into three parts: the largest, over the carpus and metacarpal region, is oval and rounded, and extends somewhat to the ventral and dorsal surfaces of the foot; the second is about half the size, and situated over the outer edge of the first phalanx of the first digit (the thumb being vestigial and not externally recognisable); the third still smaller, and situated on the outer edge of the second phalanx of the same digit. If the pollex is counted as the first digit, then the one bearing the pad is the second. There is no callosity on the other digits. After the breeding-season, in other words when the annual reproductive condition of the Frog comes to an end, the horny layer of the pads is shed, and, so far as I know, this shedding is independent of the shedding of the horny epidermis as a whole. The pads, however, do not entirely disappear in the interval between successive breeding-seasons, although they are smaller and less deeply coloured. The hypertrophy of the epidermis is accompanied by enlargement of the dermal glands beneath, but the glands are not specially considered in this paper: I believe their enlargement is part of the effect of the causes which have produced the hypertrophy of the epidermis—in fact, they are to be considered as belonging to the epidermis since their secreting epithelium is derived from and continuous with that layer.

The nuptial callosities are absent in the female. It is generally assumed that they give the male a firmer hold of the female in the axillary amplexus which precedes spawning and fertilisation. I do not desire to contradict this assumption, but in my opinion it affords no approach to an explanation of the evolution of the structures and their restriction to one sex. I have put forward a Lamarckian theory of the evolution of such secondary sexual or

epigamic characters and their heredity\*. From the Lamarckian point of view the question is not what is the use or function of a structure, but what is its cause—that is, what is the stimulus which could, on Lamarckian principles, have given rise to it.

In connexion with the controversy concerning the statement of Dr. Kammerer that he had by keeping specimens of *Alytes obstetricans* at a high temperature caused them to spawn in water, and that as a result after from two to five generations they had developed nuptial callosities, the question had occurred to me, why, if the callosities were due to friction of the hand or arm of the male against the skin of the female, the part of the female skin which is in contact with these callosities had not evolved similar structures. The callosities characteristic of the male are not present on the hands or arms of the female, but this is because the male epigamic structures are not developed in the female. This is, of course, the general rule in male epigamic characters; they are either absent or rudimentary in the female. But, on Lamarckian principles, if friction with the skin of the abdomen of the female is the original cause of the evolution of the male nuptial pads, it would be expected that the abdominal skin of the female would have developed callosities in consequence of friction with the fore-legs of the male.

During the last breeding-season I carefully studied the action and position of the arms of the male in amplexus, and found that although the nuptial pads are partly in contact with the skin of the female they are also in contact with each other, and that the more the female struggles the more tightly the pads are pressed together. The pads are also supported by the bones over which they are situated, whereas the skin of the female which is in contact with the hands of the male covers the soft abdomen and offers no resistance to pressure. It must be admitted, however, that the skin of the female against which the male hands are pressed often shows abrasions of the superficial epidermis, and it seems therefore surprising that no epidermic hypertrophy occurs. The actual contact of the pads of the male with each other only occurs when the male is nearly equal to the female in size, so that the arms are long enough to meet on the ventral surface of the female. When the male is smaller the hands do not meet, but this is only a temporary condition: if the male lives to grow larger, he will press the pads together in amplexus.

Pl. 24 is a reproduction of a photograph of a pair of living frogs in amplexus from the ventral side. At first it seemed a difficult undertaking to photograph the animal during life, and I thought it would be necessary to do it through the bottom of a glass vessel. But I found that the male did not relax, but rather increased his hold when taken out of the water,

\* Arch. f. Entwicklungsmechanik, Bd. xxvi. 1908, p. 372. 'Hormones and Heredity,' London, Constable & Co., 1921.

and that when the two were inverted and resting on the male's back, it only required a little patience to hold them in that position till they became quiet, and then they would remain still for a minute or more, during which it was easy to make an exposure.

My colleague, Mr. F. M. Haines, B.Sc., of the Botanical Department of East London College, very kindly placed his skill and experience in photography at my service and made the exposures, and the developing and printing were carried out with the photographic equipment of the Botanical Department by kind permission of Prof. F. E. Fritch, D.Sc. To both these friends I desire here to express my sincerest thanks.

It will be seen in the photograph (Pl. 24) that the two inner fingers of one hand lie between the nuptial pads, and that the metacarpal callosities are partly in contact with the female skin. But when the female struggles the two pads are forcibly pressed together.

Comparison with the Common Toad, *Bufo vulgaris*, partly supports and partly contradicts the conclusions which may be drawn from the facts concerning the frog. The callosities in the male toad are much less developed than in the frog. The thickening is slight on the metacarpus, occurs over the whole of the dorsal side of the first digit, and is present also on the dorsal side of the second digit and on the inner side of the third digit. The male is much smaller than the female, and in amplexus the hand is doubled up into a fist, which is pressed into the skin of the female, forming a pit towards the dorsal boundary of the axilla. Thus the arms of the male do not extend to the ventral side of the female at all. We can only say that the greater size of the callosities in the male frog corresponds to the fact that they are pressed against each other.

The sexual habits and the nuptial callosities of other Anura are well described by G. A. Boulenger in his excellent little book, 'Les Batraciens, Bibliothèque de Zoologie' (Douin et Fils, Paris, 1910), and in his 'Tailless Batrachians of Europe' (Ray Society, 1897). I have examined the specimens in the British Museum (Natural History) and compared them with Boulenger's descriptions. In most of the species, specimens of couples in the state of amplexus are preserved, so that the natural relative positions of male and female can be studied, and the areas of skin in contact with each other can be observed, although of course it is possible that a certain amount of shortening of the arm of the male has occurred in the dead and preserved animals. The details considered here are very clearly shown in the figures illustrating the works of Boulenger quoted above, especially the little treatise in French.

The following is a systematic list of the European genera and some of the principal species to which I shall refer :—

**Firmisternia.****RANIDÆ.***Rana temporaria* and other species.**Arcifera.****BUFONIDÆ.***Bufo vulgaris.***DISCOGLOSSIDÆ.***Discoglossus pictus.**Bombinator igneus* and *pachypus.**Alytes obstetricans.***PELOBATIDÆ.***Pelodytes punctatus.**Pelobates fuscus* and *cultripes.*

In all the species of Discoglossidæ and Pelobatidæ above mentioned the amplexus is lumbar. In *D. pictus* the fingers of the male do not actually meet below the loins of the female in the coupled specimens in the Natural History Museum, but evidently could do so in life. There is a black callosity on the inner surface of the metacarpus, about the same size as in the Common Toad, and another on the dorsal surface of each of the first and second digits. The male has also closely crowded minute black horny papillæ on the chin and pectoral surface and on the hind-legs. With regard to these horny papillæ on the ventral surface of the male, there is evidence of a reciprocal effect between the male and female; for the ventral skin of the female has minute epidermic papillæ and not larger warts, while the dorsal skin of the male has warts and not papillæ. The ventral papillæ of the male are hypertrophied where the skin is in contact with the dorsal skin of the female, and this dorsal skin shows enlarged warts where it is in contact with the ventral skin of the male, that is in the posterior region, while in the anterior dorsal region of the female which is not in contact with the male during amplexus the warts are smaller and less prominent, and similar to those of the male.

Of *Bombinator* there are two species—*B. igneus*, known as the Fire-bellied Toad, with the ventral skin red, and *B. pachypus*, which is yellow ventrally instead of red. I have examined a pair of *B. pachypus* in the British Museum (Natural History) preserved in the state of amplexus. Only the tips of the digits meet beneath the loins of the female. There are two black callosities on the inner side of the fore-arm, the proximal one the larger, and also slight ones on the inner edge of first, second, and third digits. The radial callosities are in contact with the skin of the female, and also apparently those on the inner edges of the digits, though it is possible that

in life these may be in contact with those of the opposite side. There are also small callosities on the lower surface of the second, third, and fourth toes of the hind-foot, which are probably rubbed against the female during amplexus. The radial callosities here are in contrast with those of *Pelodytes* mentioned below. We have thus three cases with lumbar amplexus to compare : *Discoglossus*, with no radial callosities, although the fore-arm is in contact with the female ; *Bombinator*, with similar contact and well-developed radial callosities ; and *Pelodytes*, in which the radial callosities are in contact with those of the opposite side and not with the skin of the female.

*Alytes*, as is well known, spawns on land : the amplexus is lumbar until the ova are discharged, and of short duration, and there are no nuptial callosities. The male carries the eggs attached to his hind-legs, and the tadpoles escape into the water. It is sometimes stated that he goes into the water in order to let the tadpoles escape ; but, in fact, he frequently visits the water at night, and probably the tadpoles escape when they are sufficiently developed, at one of these periodical visits.

*Pelobates* is the Spade-footed Toad. There are two species, *fuscus* and *cultripes*, occurring in the South of France. There are no true callosities in either. In *P. fuscus*, however, there are at the reproductive season little granular excrescences without colour scattered on the upper surface of the fore-arm and fingers. These parts are in contact with the female in the lumbar amplexus. But the radial surface on which callosities are wanting also comes into contact with the female. The fingers of the male only just meet on the ventral side. On the dorsal and outer surface of the upper arm there is a large smooth oval gland, to which the strong odour of garlic emitted by the animal is probably due. I know of no indication of any stimuli which could cause the development of a local skin gland. In the specimens of *P. cultripes* which I examined at the Natural History Museum the gland on the upper arm was scarcely visible and I could not detect any granular excrescences.

The important point in relation to *Alytes* is that *Pelobates* breeds in the water, while during the rest of the year it burrows into loose soil or sand with its metatarsal tubercle, the edge of which is formed by thickened horny epidermis of black colour. This resembles the horny epidermis of the sexual callosities, and is related to friction with the soil. This structure offers an excellent example of the difference between the functional, teleological, or selection point of view and the Lamarckian. The function is to dig into the soil, into which the animal sinks backwards, but this is no explanation of the origin of the organ. The Lamarckian theory is that the use of the hind-feet for digging into the soil was the cause of the hypertrophy of the epidermis and dermal tissue, which constitutes the digging organ.

With regard to the duration of the amplexus, the brevity of which is probably the cause of the absence of callosities, G. L. Boulenger \* states that at the time of pairing, at which period pools or deep ditches are resorted to, the female is seized round the waist, and the eggs are expelled either immediately or within a few days. Miss Dickerson † writes of *Scaphiopus holbrookii*, the American Spade-foot, that it is likely to remain in the water for breeding only one night or two at the most. Gadow ‡ says about a week for the European *Pelobates*.

It is a remarkable fact that of the two European genera of the Family Pelobatidæ, *Pelodytes* offers a maximum and *Pelobates* a minimum of nuptial callosities.

*Pelodytes* offers the most striking instance of mutual contact between the callosities of the male. The amplexus is lumbar, the pelvic region very narrow, and consequently the arms of the male meet on the ventral side of the female not at the hands, but at the elbow-joint, and the whole of the fore-arm and wrists are in mutual contact. In this position the callosities are actually in contact with each other and not with the skin of the female. There is an elongated callosity on the inner side of the fore-arm, and on the first and second digits slight ones which are partly dorsal and partly on the inner edges of the digits. The palms of the hands are turned away from the ventral surface of the female, and the two digits mentioned are towards each other if not always in contact. The other two digits are not in contact either with each other or with the female.

These parts of the arms would support the idea that the callosities were generally due to mutual contact with each other; but, on the other hand, there is a callosity on the ventral side of the upper arm and another on the pectoral surface at the base of the arm which are in contact with the skin of the female. *Pelodytes* has also minute horny papillæ on the ventral surface, a single series along the mandibular bone and others closely crowded on the posterior part of the ventral surface of the body and on the thighs. Like *Discoglossus* it has in addition slight linear callosities on the lower sides of the toes.

It is not the case, therefore, that the callosities occur only in parts of the skin of the male which press or rub against each other. It seems possible that where they come into contact with the skin of the female only, as on the fingers of the toad, the reason why callosities occur in the male only, and not in the skin of the female which is in contact with them, may be that the skin of the male on the arms or fingers is situated outside parts of the bones with little tissue in between, while the skin of the female which is in contact with the arms of the male is over the soft abdomen, and

\* 'Tailless Batrachians of Europe,' Ray Soc. 1897.

† 'The Frog Book,' New York, 1907, p. 55.

‡ 'Cambridge Natural History, Amphibia,' London, 1901, p. 163.



AMPLEXUS OF COMMON FROG.





therefore yields to the pressure, and the epidermis is not irritated or stimulated to the same degree. Apart from theory, it is evident that the callosities occur only where pressure and friction are exerted. In comparing Frog and Toad we see that the callosities are much larger and thicker in the frog, where they are pressed against each other, than in the toad, where they are in contact only with the female skin. Another very important factor in relation to the presence or absence of callosities is the duration of the amplexus, which in *Pelobates* and *Alytes* is very short, probably not more than a few hours within the limits of a single night.

The nuptial excrescences in some other extra-European genera take more surprising forms, such as conical spines. There is no need to discuss all these here ; they present the same questions as those mentioned above. There is one case, however, concerning which a correction is required. In Boulenger's little volume, already cited, *Hyla dolichopsis* of New Guinea is stated to have a curved humeral process in the male. Mr. Malcolm Smith, F.Z.S., drew my attention to the fact that von Kamper described the same species, not as having a process on the humerus, but as having the omosternum ossified and projecting in the male. I was able to verify this in the Museum specimens, but could not distinguish any females among them.

Dr. Malcolm Smith\* has described several species of *Rana* allied to *Rana doriae* Boulenger in Siam and neighbouring regions in which in the males the head is enlarged, anterior tooth-like processes of the mandible developed, and a smooth prominence of fibrous tissue present on the top of the head. He does not describe the habits of these frogs, but it seems to me probable that, unlike other Anura, they fight with one another for possession of the females, using their heads and jaws. If this is the case, there might be increased use of the head- and jaw-muscles, mechanical stimulation of the lower jaw in biting, and blows on the top of the head corresponding to the fibrous callosity.

\* "Frogs allied to *Rana doriae*," Journ. Nat. Hist. Siam, vol. iv. no. 4, 1922, p. 215.

#### EXPLANATION OF PLATE 24.

Photograph of living specimens (male and female) of *Rana temporaria* in amplexus, placed on a board without water, resting on the back of the male, with ventral surface of female upwards ; camera in vertical position with lens directed downwards.



Notes on the Segmental Excretory Organs of Crustacea.—I-IV. By H. GRAHAM CANNON, M.A., D.Sc., F.R.S.E., F.L.S., Professor of Zoology, Sheffield University, and Miss S. M. MANTON, B.A., Yarrow Student of Girton College, Cambridge. (From the Zoological Department of the Imperial College of Science and Technology, South Kensington.)

(Text-figures 1-7.)\*

[Read 20th January, 1927.]

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- IV. On the Antennal Glands of some Euphausiacea and of the Penæid Prawn *Gennadas elegans*.

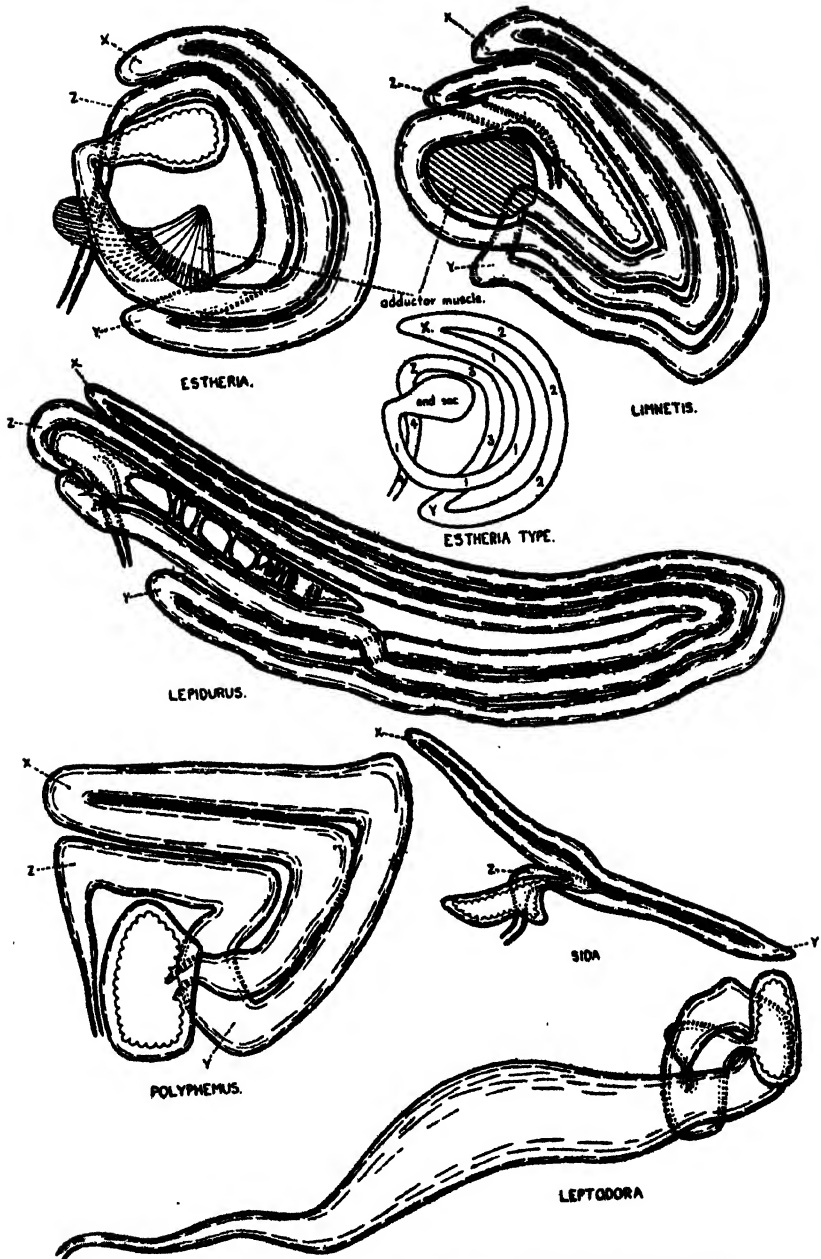
### I. THE PATTERN OF THE MAXILLARY GLANDS IN THE BRANCHIOPODA AND IN *ANASPIDÆ*.

The coils of the efferent duct of the maxillary gland of the Branchiopoda exhibit a very constant pattern and can all be traced from the arrangement seen in *Estheria*. In this form the duct leaves the end sac antero-ventrally, and curving underneath the attachment of the adductor muscle to the carapace passes upwards and forwards over the top of the end sac to a point marked X in text-fig. 1. This point is situated in the angle formed by the attachment of the dorsal longitudinal muscles and the levator muscles of the mandibles. This loop of the duct is marked 1 in text-fig. 1. The duct then turns back on itself, passes backwards, downwards, and then forwards, thus forming a second loop marked 2. It has now reached the point Y just below the end sac. It again reverses its direction and running parallel to the loop 2 reaches a point Z immediately below X, where it loops round the junction between the end sac and the remains of the first dorsal coelomic sac (Cannon, 1924, p. 403), and then passes ventrally to its opening on the maxilla. The loop between Y and Z has been marked 3, and the portion of the duct between Z and its exit has been marked 4.

This pattern, the development of which has been dealt with in detail by Cannon (1924), is the same as that shown, according to Nowikoff, in the nearly allied genus *Limnadia*, and can be taken as typical of the order Conchostraca. The other orders of the Branchiopoda can be placed in two

\* The cost of the text-figures has been met from the Westwood Fund.

TEXT-FIG. 1.



Reconstructions of the maxillary glands of various Branchiopoda.  
That of *Sida* is after Claus.

groups—the Notostraca and Cladocera, on the one hand, in which the pattern of the maxillary gland duct is closely similar to that of the Conchostraca, and the Anostraca in which there are important differences.

The anatomy of the maxillary gland of *Apus* has been described by Claus, and, allowing for certain obvious inaccuracies, it is essentially the same as in *Estheria*: firstly, he states (1893) that the loop 1 joins the loop 4 before the latter opens to the exterior. This would mean that there were two channels leading from the end sac to the exterior, one long and coiled *via* the loops 1, 2, 3, and 4, and the other short and direct *via* the loop 4 alone. From the fact that otherwise the gland so closely resembles that of *Estheria*, we think it most probable that Claus is incorrect. The second point on which we disagree with Claus's account is that he states that loop 3 encircles the "schalenmuskel." By this, presumably, he means an adductor muscle. We can find no trace of such a muscle, and Zaddach (1841) in his account of the musculature does not mention it. By comparing our own preparations of *Lepidurus*\* with Claus's figures of *Apus*, it is clear that there is no essential difference between the glands of the two forms, and in *Lepidurus* there is certainly only one channel leading from the end sac to the exterior, and there is no adductor muscle (text-fig. 1). Apparently what Claus mistook for the attachment of an adductor muscle was the fenestrated portion of the end sac. The end sac of *Lepidurus* has a peculiar shape. It is produced into three lobes. Two of these are short and project into the cavity of the trunk, while the third is an elongated and fenestrated lobe projecting into the shell-fold between loop 1 ventrally and loop 3 dorsally. It occupies the area Claus mistook for the attachment of the adductor muscle. In the young specimens that we sectioned we have not been able to find any trace of a sphincter valve.

The form of the maxillary gland both of *Lepidurus* and *Apus* can be considered as that which would be obtained if the adductor muscle of *Estheria* were removed and the space so left obliterated by the coils of the gland being pressed together, and then the whole structure stretched out in an antero-posterior direction. The maxillary gland of the Conchostracan *Limnetis* shows an interesting intermediate stage between *Estheria* and *Lepidurus* (text-fig. 1). Posteriorly its coils and end sac are crowded closely together and are compactly elongated, as in the Notostraca, while anteriorly the adductor muscle is present and it has the typical form of *Estheria*.

Among the Cladocera it is remarkable that it is in the Gymnomeran *Polyphemus* that a pattern most similar to that of *Estheria* is found (text-fig. 1). In this form, with the shifting of the surface of attachment of the adductor muscle from the outer ectoderm of the shell-fold on to the inner surface of the coils, that part of loop 1, which in *Estheria* passes forwards underneath the adductor muscle to enter the end sac anteriorly, has shortened

\* We have to thank Prof. D. M. Fedotov, of the University of Leningrad, for kindly supplying us with specimens of *Lepidurus*, *Limnetis*, and *Estheria*.

so that it now enters the end sac posteriorly. Otherwise the gland shows the typical *Estheriid* form. The maxillary gland of the aberrant Gymnomeran *Leptodora* was figured by Weismann (1874), but the arrangement of the coils is not at all clear. Calman's statement that the gland does not lie in the thickness of the shell-fold is not strictly correct. The end sac and a small coil lie laterally in the posteriorly placed carapace, and from this a large duct, probably representing loops 3 and 4, runs forward to the opening on the body-wall (text-fig. 1). The pattern of the coils is very simple; and it is not possible to make any comparison of value with that of *Estheria*.

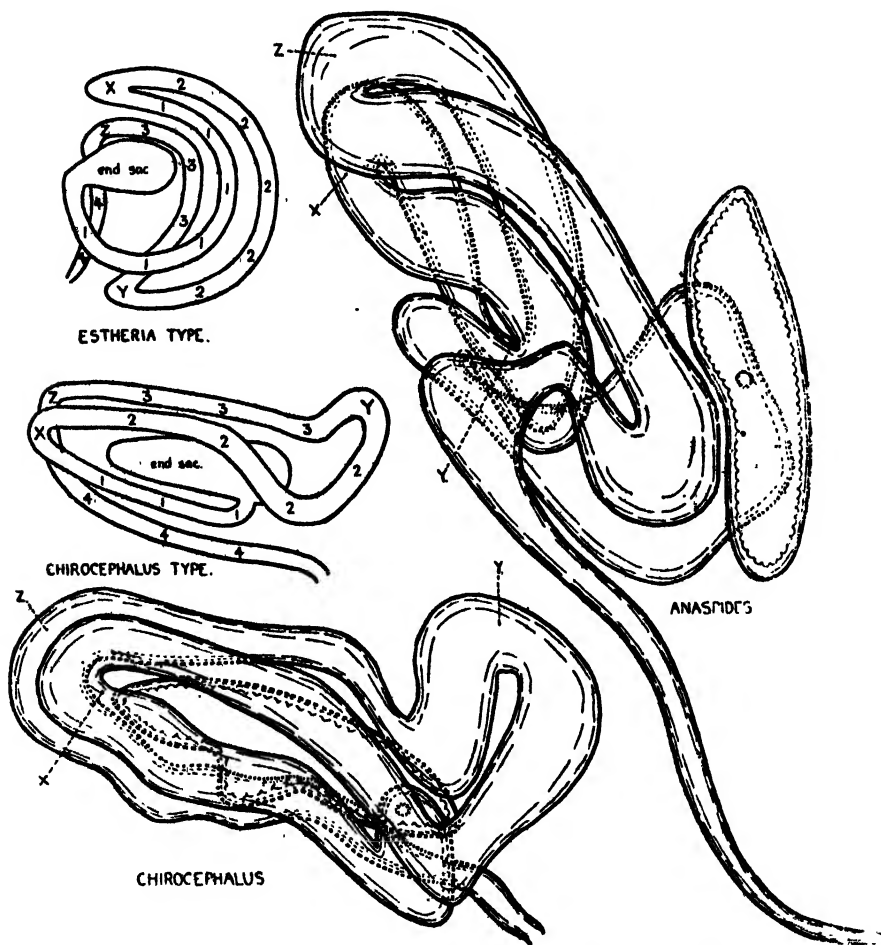
The ducts of the Calyptomeran Cladocera have been described by Claus (1875), but unfortunately the orientation of his figures is not stated and so it is sometimes difficult to interpret them. The main characteristic throughout the suborder is that the loops 2 and 3 have straightened out, so that the point Y has come to lie posteriorly or ventrally. This is best seen in the less specialised Ctenopoda—e.g., *Sida crystallina* (text-fig. 1). In the Anomopoda the loop 2 develops an S-shaped twist, e.g., in *Simcephalus*, and in a more pronounced degree in *Daphnia pulex* and *magna*, this bringing the point Y more ventral. The relation of the adductor muscle to the coils is not illustrated by Claus. However, in *S. vetulus*, in which the muscle is double, a minute strand apparently corresponding to the adductor muscle of the Conchostraca ends against the outer fold of the shell just above loop 1, but the main part of the muscle ends against the ectoderm where this reflects to form the shell-fold, and so does not interfere with the looping of the duct.

The differences in the pattern of the maxillary gland in the Anostraca, as exemplified by *Chirocephalus*, are undoubtedly connected with the absence in this suborder of the carapace and the resulting disappearance of the adductor muscles. In the other suborders the coils are lodged within the narrow cavity of the shell-folds, and there is no room for the loops to overlap to any marked degree. In *Chirocephalus* this restraining influence is absent, and so the gland projects into the body-cavity as a more or less round mass in which the loops overlap (text-fig. 2). This makes comparison with *Estheria* somewhat difficult, but there are two angles in the coils which agree completely with the corresponding points in the other Branchiopoda, and these give the clue to the homologies of the various loops of the glands. These we believe to be the points X and Z. In *Chirocephalus*, as in *Estheria*, they occur from the earliest appearance of the primordia of the coils, lodged in the angles between the anterior attachment of the dorsal longitudinal muscle and the levator muscle of the mandible. From one of them a duct leads directly to the exterior, and so this must be the point Z. From the other, X, a loop leads direct to the end sac. This is the loop 1; but, owing to the absence of the adductor muscle, it does not show the characteristic downwards and upwards loop which in *Estheria* is necessitated by its passing underneath the adductor muscle attachment. The point Y in *Chirocephalus*

has passed backwards, so that the loops 2 and 3 have become straightened out as in the more primitive Daphnids.

In the Syncarid Malacostracan, *Anaspides*, the pattern of the maxillary gland shows a very striking and significant similarity to that of *Chirocephalus* (text-fig. 2). As in the latter there are two angles in the coil that occupy

TEXT-FIG. 2.



Reconstructions of the maxillary glands of *Chirocephalus* and *Anaspides*.

the space between the anterior attachment of the dorsal longitudinal muscle and the levator muscle of the mandible. From one of these a loop runs directly to the end sac, with, in the middle of its length, an S-shaped twist, and this must be the loop 1 running from the point X. The loops 2 and 3 running posteriorly from the points X and Z respectively are straight and

are comparatively short, so that the point Y comes to lie anteriorly to the end sac. Thus, except for the minor difference in the S-shaped twist occurring in loops 1 and 4, there is a complete agreement between the pattern of the coils of *Anaspides* and *Chirocephalus*.

The occurrence of the looping of the coils of the maxillary glands of two such different forms as *Anaspides* and *Chirocephalus* probably indicates nothing more than a similar physiological necessity, but the occurrence of a similar pattern in that looping we consider as more significant. We see no reason for attributing it to mere chance, and we think rather that it should be taken as an indication of a phyletic relationship.

From sections of some specimens of *Bathynella* that we were fortunate enough in obtaining through the kindness of Professor Zschokke, it is clear that the pattern of the looping of the duct cannot be compared with that of *Anaspides*. The attenuated form of the body has drawn out the duct into a long loop extending from the maxillary segment to the fourth trunk segment. The chief interest in the gland lies in the fact that, presumably as a result of the minute size of the adult, the duct has become intracellular.

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#### II. ON THE SPHINCTER VALVES OF THE MAXILLARY GLANDS OF *CHIROCEPHALUS* AND *ANASPIDES*.

In *Estheria* there is no sharp distinction between the end sac of the maxillary gland and its duct. The end sac appears simply as the enlarged internal termination of the duct. The end-sac cells are flatter than those of the duct, but there are no marked histological differences between them. In *Limnadia*, according to Nowikoff (1905), the cells of the end sac differ considerably in their histological detail from those of the duct. But neither in *Estheria* nor in *Limnadia* is there any indication of a muscular valve between the end sac and the duct.

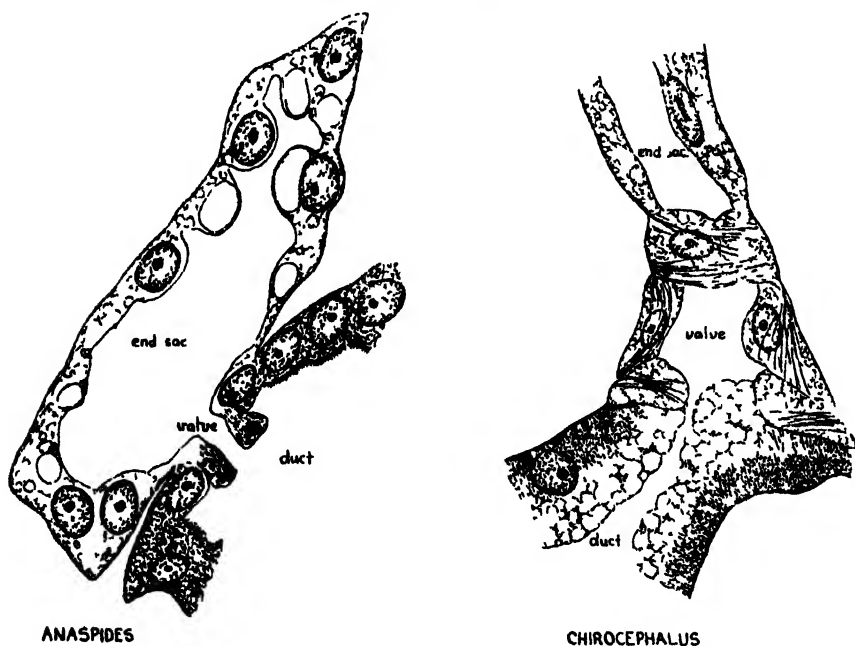
In *Chirocephalus*, however, not only is there a marked difference between the cells of the end sac and those of the duct, but in between the two there occurs a very well-defined muscular sphincter. In the adult the cells of the



end sac immediately surrounding the entrance to the duct exhibit very clearly deeply staining fibrils. About eight cells in all form the valve, the fibrils running transversely to the direction of the duct. The distinction between the end sac and the duct is very marked in early larval forms, long before the lumen has appeared in the duct. The end-sac cells are much more vacuolated than those of the duct and the cytoplasm does not stain so readily. From a study of the development it can be seen that the valve arises from the end-sac portion of the gland. A muscular sphincter has not been described in the maxillary gland of any other Branchiopod.

In *Anaspides*, as in *Chirocephalus*, the end sac is clearly differentiated from the efferent duct, and at the junction between the two there occurs a definite

TEXT-FIG. 3.



Sections through the maxillary gland valves of *Anaspides* and *Chirocephalus*.

valve. This consists of a group of three or four cells around the entrance into the end sac which project very markedly into the lumen of the duct. The detailed histological constitution of the valve unfortunately could not be made out, as the fixation of the specimen was not sufficiently good (text-fig. 3). It resembles, however, very closely the valves of the excretory glands of *Niphargus* and *Gammarus* described by Vejdovsky (1901).

The close similarity in the pattern of the maxillary glands of *Chirocephalus* and of *Anaspides* we take as clear evidence for the complete homologies of the two glands. That of *Chirocephalus* has been shown by Cannon (1926) to

consist of an entirely mesodermal structure. We therefore deduce that the maxillary gland of *Anaspides* is similarly of mesodermal origin, and hence the valve, which in *Chirocephalus* is differentiated actually from the end-sac walls, is also mesodermal. The chief interest in the discovery of a mesodermal valve in *Chirocephalus* and in *Anaspides* lies in the fact that Cannon has recently demonstrated that the valves of the maxillary glands of certain fresh-water Ostracods (1925) and of the antennal gland of the larva of *Chirocephalus* (1926) are of ectodermal origin. He believes that in these two cases the valves represent portions of the endoskeletal system that have secondarily become intercalated between the end sac and the duct. In an advanced larva of *Chirocephalus* there are therefore two segmental excretory organs, the antennal and the maxillary glands. Both show the typical structure of an end sac, a valve and a duct, and it is reasonable to suppose that in both cases the corresponding parts function in similar ways; but whereas the valve of one (the antennal gland) is ectodermal, that of the other (the maxillary gland) is mesodermal in origin.

Vejdovsky (1901, p. 294) suggested that the valve-apparatus represented the annelid nephrostome. He considered only the complex nephrostome such as occurs in *Lumbricus* and into the constitution of which mesodermal elements enter. In such a structure the mesodermal portion separates the inner mesodermal structures from the outer ectodermal portion of the nephridium. In *Chirocephalus*, and presumably in *Anaspides*, the whole maxillary gland is mesodermal, and thus the valve in separating the end sac and the duct separates two mesodermal structures, so that the valve cannot be homologous with this type of nephrostome.

Cannon has already demonstrated (1925) that the ectodermal type of valve also cannot represent the annelid nephrostome. It is an independent structure arising separately from the ectodermal duct, whereas the ectodermal nephrostome of an annelid always arises as the inner termination of the ectodermal ingrowth to form the nephridium.

The ectodermal valve we have found only in glands where the duct is of the intracellular type and, therefore, according to Cannon, is also an ectodermal structure. In the antennal gland of *Estheria* and *Chirocephalus* and in the maxillary and antennal glands of *Cypris* the ducts are all intracellular, and in each case there is a valve which there is reason to believe is of ectodermal origin (1926). In a Cirripede nauplius we have found an antennal gland in all essentials similar to that of a Branchiopod. It has an intracellular duct of a few cells only and a valve attached to the ectoderm as in *Chirocephalus*. In the Copepod nauplius, according to Grobben (1881, p. 264), the antennal gland also possesses an intracellular duct but apparently no trace of a sphincter. In this connection it is interesting to note that the nauplii of the four orders of the unjustifiable group Entomostraca all possess antennal glands with intracellular ducts. In the nauplii of certain

Euphausiids, the only Malacostracan nauplii we have been able to obtain, there is, however, no trace of antennal gland.

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### III. ON THE SEGMENTAL EXCRETORY ORGANS OF THE MYSID

#### *LOPHOGASTER TYPICUS*.

Of the Peracaridan Malacostraca, the Mysidacea represent the order which is most directly related to the ancestors of the division, and it is generally accepted that from some primitive Mysid there arose, on the one hand, the modern Mysids and the Amphipods, and, on the other, the Isopods—the Cumacea and Tanaidacea being offshoots from this latter stem.

The segmental excretory organs of the Amphipoda are the antennal glands, and the same is usually stated with regard to the Mysidacea. In the Isopoda, Cumacea, and Tanaidacea, however, it is the maxillary glands that constitute the segmental excretory organs. In all these orders the antennal glands may be present during embryonic stages, but they are completely absent in the adult.

It would be expected from this that the common stock which gave rise, on the one hand, to the Amphipoda and, on the other, to the Isopoda would have possessed both antennal and maxillary glands. From a comparative study of the anatomy of the excretory organs of the group, it could further be predicted that in this primitive form the glands would consist of a simple end sac with a multicellular duct which was probably more bladder-like than tubular.

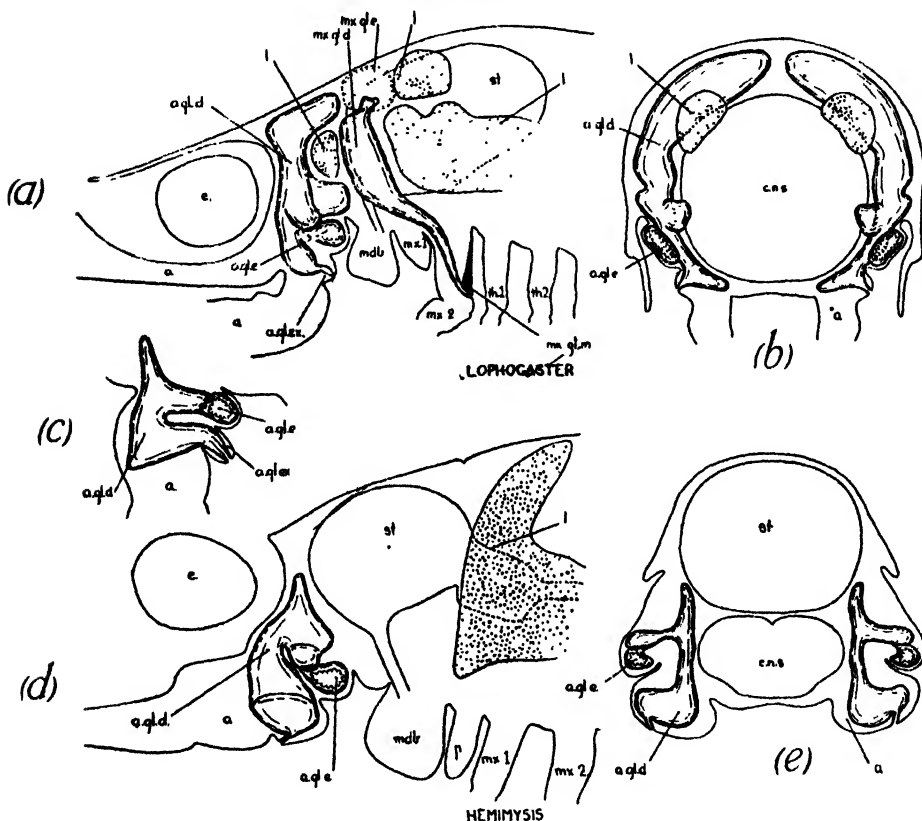
The Lophogastridae are usually considered to be a primitive family of Mysids. Through the kindness of Dr. Calman we have been able to examine the segmental excretory organs of *Lophogaster typicus*. The specimens were taken from deep water many years ago, and no special precaution had been taken to ensure good fixation. The preservation, however, was remarkably good. We find, as we expected, that the adult

possesses antennal and maxillary glands, both well developed (text-fig 4, *a* and *b*). We have been able to reconstruct the glands from sections, with the exception of the end sac of the maxillary gland, only remnants of which were preserved. Both glands are similar in structure, and closely resemble the antenna gland of *Hemimysis lamornæ* (text-fig. 4, *d* and *e*). The end sac of the antennal gland is simple, and the ducts of both are large and swollen, but not coiled. The antennal glands of both *Hemimysis* and *Lophogaster* are roughly shaped like an inverted Y. The two arms of the Y pass to the end sac and exit, the latter extending more ventrally than the former. The tail of the Y lies up the side of the body as a blind lobe. In *Lophogaster* this lobe reaches the dorsal side of the body, curling round the brain. In *Hemimysis* it is much shorter, the space occupied by this lobe in *Lophogaster* being filled by the more anteriorly situated stomach. In both, the end sac lies in a posterior bulge at the base of the antenna, and does not communicate by a conspicuous pore with the duct. In *Hemimysis* the wall of the duct becomes thin where it is pressed against the end sac, and here a group of duct-cells extend slightly into the lumen of the duct. Through these cells can be seen some ill-defined lacunæ, which may put the end sac in communication with the duct. In *Lophogaster* the end sac is drawn out against the duct, just as in *Hemimysis*, and in one specimen a group of duct-cells in size and shape resembling those mentioned above seems to be present. The duct in both opens to the exterior by a short exit-tube of different histological character at the base of the antenna below the end-sac bulge. In *Lophogaster* the exit-tube opens on a papilla, the exit-tube occupying the whole of this structure. In the late embryo of *Hemimysis*, just before the young leaves the brood-pouch the exit-tube also opens on a papilla, exactly as in *Lophogaster* (text-fig. 4, *c*). The antenna at this stage extends downwards or backwards. When the young leaves the brood-pouch, the antenna turns forwards and the posterior papilla becomes drawn out and partially obliterated. The region of the antenna corresponding to the embryonic papilla now becomes filled with the enlarged distal part of the duct. The duct of the maxillary gland of *Lophogaster* is quite simple, and has no blind lobes. It opens at the distal end of the first joint of the maxilla, and from the exit-tube extends a large dilator muscle on the upper posterior surface of the limb.

The segmental excretory organs of *Lophogaster* can be taken as a type from which the conditions found in all the Peracarida can be derived. A simple sac-like duct is found in the antennal gland of the Mysid *Siriella* and in various Isopods, such as *Gyge*, *Platyarthrus*, *Porcellio*, and *Oniscus*, some of which may show one loop. By further elongation and looping of the duct the sac-like shape will be replaced by the narrower coiled type of duct found in the Tanaidacea and Cumacea, which usually show two

loops, and in *Asellus*, *Gammarus pulex*, *Niphargus*, and a Mysid, figured by Grobben (1881), in which the coils are numerous. By partial or complete suppression of one or other of the antennal and maxillary glands the conditions found throughout the orders of the Peracarida can be obtained.

TEXT-FIG. 4.



- (a) External view of a longitudinal reconstruction of the segmental excretory organs of *Lophogaster typicus*. The possible position of the end sac of the maxillary gland is indicated by the dotted line.
- (b) Transverse reconstruction of the antennal glands of *L. typicus*, viewed from behind.
- (c) Longitudinal reconstruction of the antennal gland of a late embryo of *Hemimysis lamornæ*, just before leaving the brood-pouch.
- (d) External view of a longitudinal reconstruction of the antennal gland of an adult *H. lamornæ*.
- (e) Transverse view of the antennal glands of *H. lamornæ*.

a., antenna; a.g.l.d., duct of antennal gland; a.g.l.e., end sac of antennal gland; a.g.l.ex., antennal gland exit-tube in its papilla; c.n.s., central nervous system; e., eye; l., liver; m.d.b., mandible; m.x. 1, maxillule; m.x. 2, maxilla; m.x.g.l.d., duct of maxillary gland; m.x.g.l.e., end sac of maxillary gland; m.x.g.l.m., dilator muscle of the exit-tube of the maxillary gland; p., paragnath; st., stomach; th. 1, first thoracic limb; th. 2, second thoracic limb.

Unfortunately, it has not been possible to investigate the segmental excretory organs of *Thermosbana*.

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#### IV. ON THE ANTENNAL GLANDS OF SOME EUPHAUSIACEA AND OF THE PENID PRAWN *GENNADAS ELEGANS*.

A surface-view of the antennal gland of *Euphausia superba* was figured by Zimmer (1913). He correctly described a ring-shaped duct, but did not find an end sac. Chun (1896) also described and figured a U-shaped tubular antennal gland of a deep-sea Euphausiid *Stylocheiron*, but his homologies of the duct and end sac are not at all clear.

We have examined the antennal glands of *Nyctiphanes couchii* and of *Stylocheiron abbreviatum*, and find them to be very similar. The antennal gland of *Nyctiphanes* forms a compact mass at the base of the antenna, and does not extend up the sides of the body. The end sac is simple and not lobed, and shows a one-layered epithelium. The duct is wide and sac-like, and opens by a short exit-tube on a small elevation at the ventral surface of the limb-base. The duct epithelium shows a very conspicuous striated border towards the lumen. The duct is, however, peculiar in one respect. It appears in side-view as a hollow ring (text-fig. 5, *a* and *b*) at the posterior lower end connected with the exit-tube, and joining the end sac in the middle of the upper part of the ring. Thus from the end sac there are two passages to the exit-tube, one by the dorsal and posterior part of the ring and one by the anterior and ventral part. The end sac occupies the central space of the duct. The fixation of the end sac was not so good as that of the duct, and no open communication between the duct and end sac could be found. The intimate junction between the two is, however, unmistakable, and is always characterized by a group of cells with small nuclei bulging irregularly into the lumen of the duct (text-fig. 5, *c*). There appeared indications in the sections of irregular lacunæ among these cells.

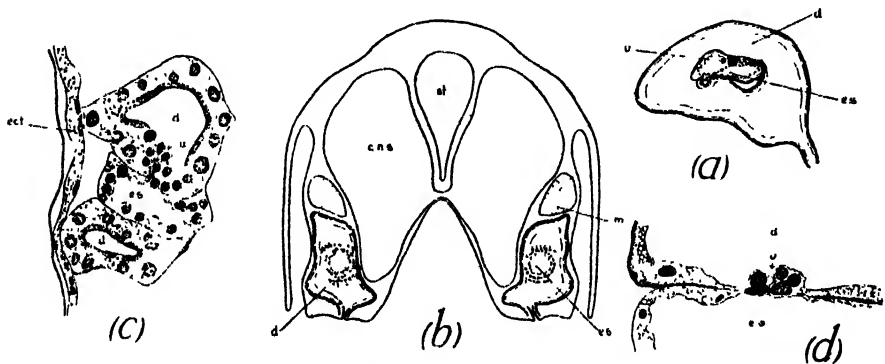
The antennal gland of *Stylocheiron abbreviatum* shows a similar pattern to that of *Nyctiphanes*, and is not a simple U-shaped structure as Chun describes. The valve between the duct and end sac is composed of fewer cells than in *Nyctiphanes*, but appears to be similar in structure. In one section (text-fig. 5, *d*) a clear narrow channel passes from the end sac to the duct between these cells.

Thus the antennal glands of *Euphausia superba*, *Nyctiphanes couchii*, and *Stylocheiron abbreviatum* all show a ring-like duct, and the valves between the end sac and duct in *Nyctiphanes* and *Stylocheiron* are also similar.

Zimmer did not cut any sections of *Euphausia superba*, and so we do not know what the valve was like in this form, but it probably resembled that of the other Euphausiids. This type of gland is probably typical of the Euphausiacea generally, and differs from all other non-labyrinthine antennal glands in the shape of its duct.

The antennal gland of the Penæid prawn *Gennadas elegans* is of interest in that the adult shows a duct which has not yet become labyrinthine; and which possesses a well-developed valvular apparatus between the duct and end sac—a condition only found, as far as we are aware, in larval Decapods. A bladder system is also well developed.

TEXT-FIG. 5.



Antennal gland of *Nyctiphanes couchii* and *Stylocheiron abbreviatum*.

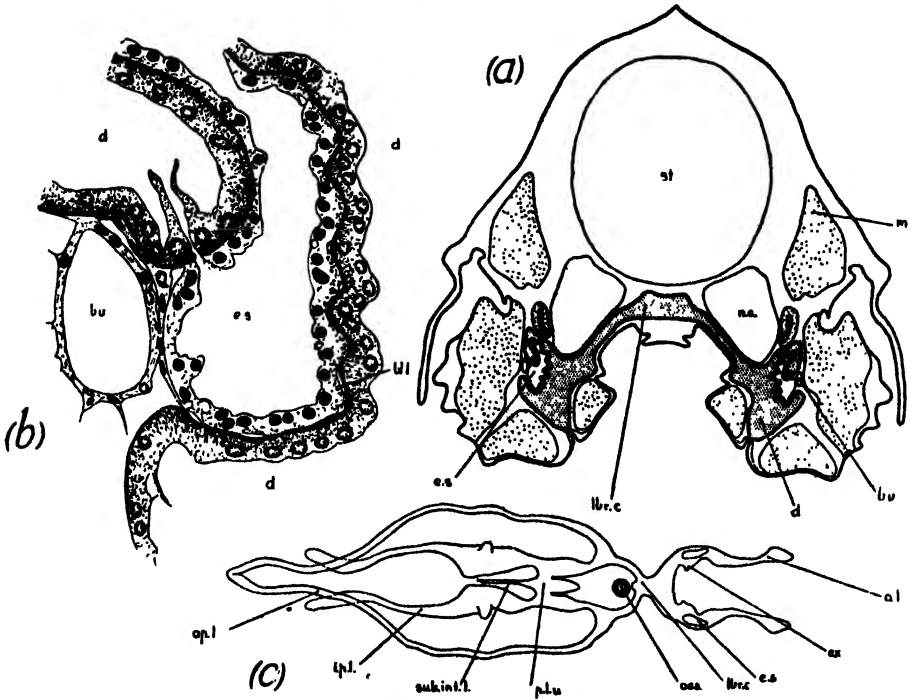
- (a) Outer view of a longitudinal reconstruction of the gland of *N. couchii*.
- (b) Transverse section showing a reconstruction of the gland of *N. couchii*.
- (c) Part of a section showing the connection between duct and end sac of *N. couchii*.
- (d) Part of a section showing the valve between end sac and duct of *Stylocheiron abbreviatum*.

c.n.s., central nervous system; d., duct of antennal gland; ect., ectoderm; e.s., end sac of antennal gland; m., muscle; st., stomach; v., connection between end sac and duct.

The gland, apart from the bladder system, is lodged in the base of the antenna between the muscles and the nerve-cord. The end sac shows a simple one-layered epithelium, and is thrown into slight folds (text-fig 6, a and b), but is practically a simple sac. The duct is sac-like, and wraps closely round the end sac, leaving it exposed only for a small region on the outer side, where the antennal gland artery lies close to the end sac. Where the sac-like duct touches the end sac it follows the same slight lobing of the latter. The duct opens by a short exit-tube on the inner side of the limb-base. The duct is wide and simple, except at the upper outer angle above and external to the end sac, where its walls are thrown into a few folds, which may extend right across the lumen. The end sac opens into the duct in the middle of its outer surface, and this opening is guarded by a valve.

This consists of about eight extremely elongated duct-cells round the entrance, projecting into the duct-lumen. No fibrils of any kind could be seen in them. In between the end sac and the duct-wall is a thin layer of connective tissue, in which are found numerous blood-lacunæ. These are supplied with blood from the antennal gland artery, which enters the gland over the exposed part of the end sac, and then spreads out over its surface.

TEXT-FIG. 6.

Antennal gland of *Gennadas elegans*.

- (a) Diagrammatic transverse section showing the end sac and duct and the labral connection between the two ducts.  
 (b) Part of a section through the antennal gland showing the communication between the duct and end sac and the valve.  
 (c) Dorsal reconstruction of the whole gland to show the bladder system.

*a.l.*, anterior lobe of bladder system; *b.v.*, antennal gland artery; *d.*, duct of antennal gland; *e.s.*, end sac of antennal gland; *ex.*, exit-tube of antennal gland; *i.p.l.*, inner posterior lobe of bladder system; *lbr.c.*, labral commissural connection of bladder system; *m.*, muscle; *n.c.*, nerve-cord; *oes.*, oesophagus; *o.p.l.*, outer posterior lobe of bladder system; *p.l.u.*, union between posterior lobes of bladder system; *st.*, stomach; *sub.int.l.*, sub-intestinal lobe of bladder system.

The bladder system is well developed, and can be seen from text-fig. 6, *c*. Anteriorly the duct gives off a pair of blind sacs reaching to the dorsal part of the bases of the antennules (*a.l.*). A transverse commissure through the



base of the labrum below the nerve-cord joins the duct-systems on each side (*lbr.c.*), and two posterior lobes extend into the thorax. These shift to the sides of the nerve-cord and divide into two. The outer lobes pass laterally close to the body-wall outside the musculature, and gradually become more dorsal in position till they reach the heart (*o.p.l.*). They then unite and are closely wrapped round the anterior part of the heart, where they end blindly. The inner lobes unite (*p.l.u.*) above the mandibular tendon and again separate. A median lobe extends backwards from this union below the stomach and above the liver (*sub.int.l.*). The posterior lobes now lie below the stomach between the liver and the musculature. They become gradually more dorsal, extending up the sides of the stomach until they lie just below the outer lobes, where they end blindly.

Of the Penæidæ the only antennal gland previously described is that of *Leucifer* (Grobber, 1891). Here also the end sac is simple and the labyrinth absent. The duct is narrow and has two coils, and is thus more reminiscent of the higher Peracaridan types than the Decapoda. The gland is, however, modified by the extreme lateral compression of the animal, the patterns of the ducts having become asymmetrical and a union established between the dorsal loops of the ducts on each side.

The typical antennal gland of a Decapod consists of an end sac, a more or less complicated duct-system leading to the exterior, divided into a ventral portion, the labyrinth, which with the end sac constitutes what is known as the "glandular" part of the organ, and a dorsal portion acting as a reservoir. The end sac is said to be typically many-layered, but this is not so in many prawns, e. g., *Hippolyte*, *Pandalus*, and *Gennadas*, or in *Cancer* and *Carcinus*. The more primitive condition may be taken to be that found in embryos and many adults, where the epithelium is single-layered and the sac not lobed. Such a simple end sac is found in the adult *Hippolyte*.

The Decapod labyrinth is formed from a simple duct by one of two methods, or a combination of both. Firstly, the duct-wall itself may become folded internally, so that partitions are formed dividing up the cavity of the duct, and, secondly, the end sac with the closely apposed duct may become lobed, so that the processes from the end sac push the duct-wall into folds and partitions. No such complications are present in *Hippolyte*, but *Gennadas* is seen to show the initial stages of both. In *Hippolyte varians* the whole gland is roughly sausage-shaped, and lies horizontally at the side of the body. The duct is bladder-like, and wraps almost completely round the end sac, which lies in the middle of the gland-mass. Anteriorly, the duct is drawn out into three short processes. The duct in *Gennadas* near its opening to the end sac shows about two folds projecting from its wall, while the rest of the duct is sac-like, and the end sac shows the initial stages of lobulation. This condition is carried further in *Pandalus*, where long end-

sac lobes project into similar folds of the duct-wall, extending into an otherwise sac-like duct.

The connection between end sac and duct, as pointed out by Burian and Muth (1921, p. 642), is provided in young stages of the Decapoda with a valve somewhat similar to the structures found in the Peracarida. Such a valve, figured by Allen (1893), for the young *Palæmonetes*, appears to be formed by the end-sac cells round the opening of the duct being very slightly enlarged. No muscular sphincter or fibrils such as occur in the Peracarida have been described. Burian and Muth point out that in the adult Decapod this valve gives place in some cases to a similar functioning, but less conspicuous structure such as is found in *Stenorhyncus*. Here an accumulation of end-sac cells round the opening to the duct occurs, reducing the size of this opening. This accumulation does not differ from the other irregular thickenings of the multi-laminar end-sac wall. The embryonic valves possessed by larval Decapods referred to above are not nearly so well formed as the similar structures in the Peracarida or the valve of the adult *Gennadas*. Thus, *Gennadas* appears to be the only Decapod described which has in the adult a well-developed typical valve between the end sac and the duct.

The bladder system of the Decapod antennal gland develops as an outgrowth from the originally simple duct. We consider that most of the homologies that have been drawn between the different lobes of the bladder system in various types are of doubtful significance. However, *Gennadas* certainly does show a bladder system that combines to a certain extent the characteristics found in both Caridea and Paguridea. The anterior lobes are characteristic of all extensive bladder systems, such as occur in the Caridea, Paguridea, and Brachyura. The transverse union between the two systems through the labrum is present just as in some Caridea, while the posterior lobes may be compared to those of the Paguridea or, perhaps, with the paired or single epigastric lobes of the Caridea. A union between the posterior lobes and a subintestinal lobe also occur in the Paguridea. It is difficult to homologise the outer lobe marked (*o.p.l.*) in text-fig. 6, a. It may represent part of the posterior lobe of the Paguridea, which unites with the paired or single bladders, and which lies between the lobes of the digestive gland or between the ovaries, or it may be a further development of the short unnamed dorso-lateral lobe figured by Weldon in various Caridea external to the naphroperitoneal sac (=epigastric lobe) (1891, plate xxi. figs. 1 & 3).

A consideration of the segmental excretory organs of the Mysidacea has led us to suppose that the primitive excretory gland of the Peracarida is a type with a simple end sac and a wide sac-like duct, and that the types with narrow coiled ducts have been derived from the former. We consider that a similar type of gland also gave rise to the conditions found in the

Eucarida. The antennal glands of larval Decapods are of this type, and that of the adult *Hippolyte* shows no great advance on this condition. The sac-like duct has become longer, and almost completely envelops the end sac. It is this tendency for the duct to envelop the end sac in the Decapoda which distinguishes them from the Peracarida, and which partly led to the development of the labyrinth, the initial stages of which are seen in *Gennadas*. In the Peracarida the duct remains free from the end sac throughout its course, and the end sac is lodged in a separate lobe of the antennal base. The condition found in the Euphausiacea may be directly

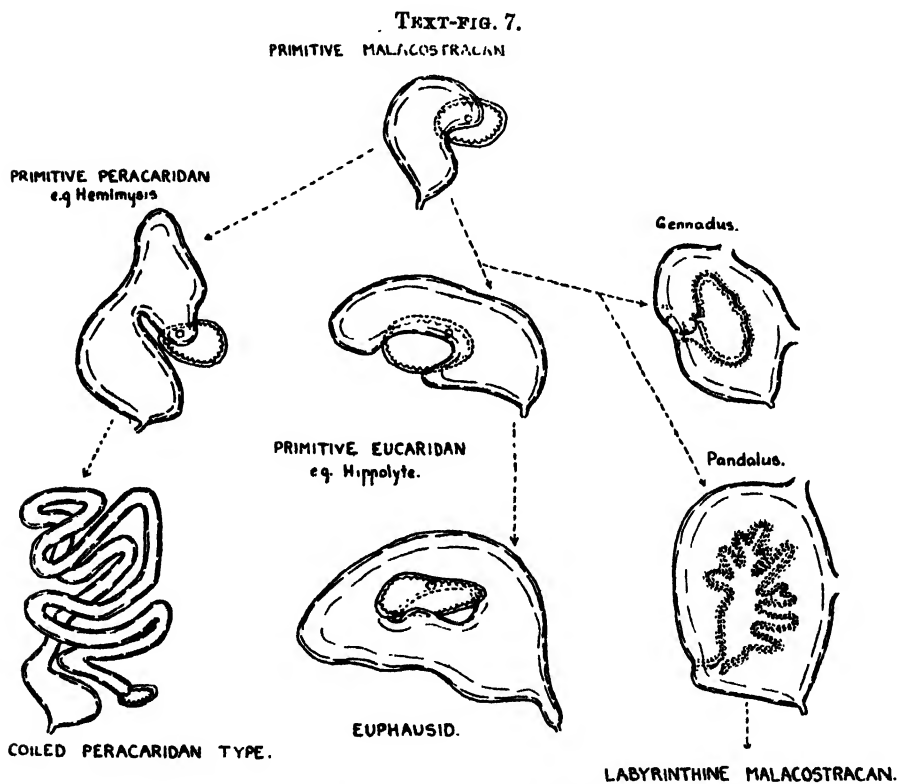


Diagram summarizing the suggested evolution of the various types of antennal gland found in the Eucarida.

derived from the *Hippolyte* type. The sac-like duct has only completely to wrap round the end sac and its two extremities will come in contact. Fusion of the duct-walls at this point would give the ring-like duct. These suggestions are summarized in text-fig. 7.

Nothing critical can be said as to the type of union between the end sac and the duct in the most primitive type, and if a valve was present or absent. It may not be without significance that in the Euphausiacea and

the Mysidacea with primitive glands (*Hemimysis* and *Lophogaster*) an open communication between end sac and duct appears absent, while an irregular group of cells, through or between which small lacunar spaces appear, is present at the junction.

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On the Relation between Egg-weight and Body-weight in Birds. By JULIAN S. HUXLEY, M.A., F.Z.S., Professor of Zoology, King's College, London. (Communicated by Dr. D. L. MACKINNON, F.L.S.)

(With PLATES 25-29.)

[Read 17th February, 1927.]

IN a recent volume of an ornithological publication there appeared a monumental paper by Heinroth (1922) on this subject. His data are given *in extenso*, and he presents the reader with a number of elaborate charts showing his results in graphical form. Although certain interesting general conclusions emerge from these charts, they give on the whole a somewhat confused impression, since he has, I think, not condensed his data sufficiently, and I have therefore been through his facts and have analysed them in a rather more radical way to see whether any more definite general relations emerged than those which he mentions. Furthermore, the subject is of such general interest to zoologists that it seems desirable to present some account of it in a less specialist periodical.

The obvious facts which Heinroth's work demonstrated were two—first that, both in birds as a whole and within separate groups of birds, relative egg-weight diminishes with increase of absolute body-weight; and secondly that each group shows a characteristic curve of its own, relative egg-weight being consistently above the average in some, consistently below it in others.

Some further conclusions are also drawn by Heinroth. For these I must refer readers to the original paper, as also for the methods adopted. With regard to these latter, Heinroth himself acknowledges that the mean weights he arrives at may not be precisely those actually obtaining in nature; but I agree with him in believing that the errors are not large and will on the average cancel out. The general regularity of the curves is in itself a presumption that the errors are not great.

Instead of trying, like Heinroth, to plot each species separately on the graph, I have adopted a system of averaging. This has been done by the simple method of grouping the species into classes, each class containing all forms whose total weights fall within certain arbitrary limits, and then taking the average of the total weights and the egg-weights for each class. The facts as thus arranged are given in Tables I. and II. (pp. 464, 465).

The results can be plotted in various ways. Heinroth has chosen to plot relative egg-weight (per cent.) against absolute total weight. When this is done, the relative weight is seen to decrease, very rapidly at first, then more slowly, and then very slowly indeed, giving a "hollow curve" very similar to those given by Willis for the relation between frequency of genera and the number of species which they contain.

The second method would be to plot absolute egg-weight against absolute body-weight (this is done in Pl. 27). Heinroth tells us that he did not do this, as it would merely show that relative egg-weight decreased with increase of body-weight. However, this is all which, in the first instance, his own method tells us. We want to know more than this, *e.g.* whether the decrease of relative egg-weight follows some definite rule in relation to absolute body-size.

I have thought best to plot the logarithm of absolute egg-weight against the logarithm of absolute body-weight (by plotting directly on to paper ruled in a double logarithmic grid)\*. I suspected that egg-weight might be a function of some power of body-weight, and if so this method of plotting would give a straight line. If for instance egg-weight were a function of body-surface, it would be a function of  $(\text{body-weight})^{\frac{2}{3}}$ , and  $\log (\text{egg-weight})$  would equal a constant  $+\frac{2}{3} \log (\text{body-weight})$ . For previous applications of this method to another biological problem, see Huxley (1924), Dubois (1922), Lapicque (1922), Klatt (1919).

The second advantage of logarithmic plotting is that one is enabled to compress a far greater range of size on to a single graph; further, on such a graph equal differences represent the important fact of equal *proportional* differences of dimensions, not the relatively unimportant fact of equal *absolute* differences. Thus the "small" end of the graph is not overcrowded, as occurs when absolute values are plotted. The results for the ten groups best represented in Heinroth's tables, and for the totals of all his figures, including members of other groups, are shown in Pls. 25 & 26. It will be seen at once that my expectation of a straight line graph is not realized. All the lines tend to become flatter with increasing body-size. Some of the curves are less regular than others. The less regular ones will be seen to be those where fewer species have been available. Curves like those of the Limicolæ, the Laridæ (exclusive of the last point), and the Oscines are remarkably regular, as well as that for the totals.

The general shape of all is very similar; but, as Heinroth noted, they run at very different levels. This gives exact expression to the fact of common observation that all the members of some groups lay relatively small, others relatively large eggs. For instance, Laridæ and Limicolæ throughout their whole size-range lay eggs about  $2\frac{1}{2}$  times as heavy as those of Oscines, about twice as heavy as those of game-birds (Galli), and about  $1\frac{1}{2}$  times as heavy as those of owls (Striges).

Somewhat contrary to my expectation, the gulls and terns (Laridæ) are seen to lay relatively heavier eggs even than the waders (Limicolæ). Marked difference in relative egg-size must be added to the numerous distinguishing

\* The use of logarithmic-grid paper is insufficiently known to most biologists, though familiar of course to all engaged in more mathematical sciences. Much labour can, however, often be saved by its use. For certain purposes the double logarithmic grid is suitable, for others paper ruled arithmetically along one axis, logarithmically along the other. Both types of paper can be obtained from any good firm of scientific instrument makers.

characteristics which made it necessary for systematists to divide the "birds of prey" into two separate and unrelated groups, the Falconiformes and the Striges. The parrots (Psittaci) and doves and pigeons (Columbæ) have relatively very small eggs, as also the other great group with nidicolous young, the Oscines. The Galli have relatively smaller eggs than most birds with nidifugous young. Apparently size is here in inverse relation to number.

It is of some interest to note that the Ratitæ (with the exception of the Kiwi, see below) fall so nearly on the general graph. As perhaps might be expected in view of their terrestrial habits, they have eggs a little heavier than would be expected if the main curve were extrapolated. None the less, their mean relative egg-weight is less than that of the largest flying birds, and the two heaviest of them, the Ostrich and *Casuarus novæ-hollandiæ*, show the lowest relative egg-weights found in any of Heinroth's figures (16.3 and 15.0 per mille respectively), considerably lower than those of the lighter Rhea and other species of Cassowary (mean, 21.2 per mille).

One of the most striking facts is the position of the common cuckoo (*Cuculus canorus*) on the graph. It is again a matter of common knowledge that cuckoo's eggs are relatively very small, but the measurements reveal that its egg is only half the relative weight of that characteristic of the groups with the next smallest relative egg-size (parrots and doves), and less than a third of that obtaining for birds as a whole. It has a body-weight more than three times as large as that of the average song-bird with an egg of the same size. Other parasitic cuckoos measured by Heinroth show similar relations. We have a particularly striking example of the power of natural selection to modify relative egg-size, since there can be little doubt that the small relative size of the cuckoo's egg is a necessary adaptation to its parasitic habits, and the difference from the relative egg-size of any other group seems too great to have been acquired as a single mutation. Further, species of parasitic cuckoos which lay in the nests of species of about the same bulk as themselves do not have unusually small eggs. The Kiwi (*Apteryx*) is also highly aberrant, but in the opposite direction. It is well known to lay relatively enormous eggs, up to 20 per cent. or more of its body-weight. The graph shows that its eggs are as heavy as the average egg of birds very nearly ten times its weight, and over four times as heavy as the egg of birds averaging the same body-weight as itself.

Another interesting fact revealed by the graph is this. Not only are curves which start at about the same absolute body-weight of similar shape, but even curves which start at markedly different body-weights. That is to say, all the curves, irrespective of their point of origin, tend to start steeper and to end flatter. This will have the effect of bringing about the intersection of curves of groups with about the same relative egg-weight but different size-ranges. For instance, the Oscines start very small, with body-weights well below 10 g. The first point on the pigeons' curve is at 35 g

The pigeon curve is still ascending fairly rapidly when the song-bird curve is flattening out, and as a result the two curves intersect at a body-weight of about 250 g. The same phenomenon, of the relative egg-weight of a group of smaller mean body-size starting above, but ending below, that of a group of larger mean body-size, is seen in several other places in the graph. Thus there is an intersection of the curves for Limicolæ and for Falconiformes (small) with that for Anseres (large) (Pl. 28), of Striges with Otididæ, and of Psittaci\* and Oscines. Limicolæ and Laridæ would probably intersect if slightly smaller Laridæ existed.

In the most general terms, then, the relation between egg-size and body-size is only in part a function of absolute size. It is largely a function of small or large size *within a group with a definite size-range*. With an increase of absolute size of a certain proportionate amount, starting from the smallest absolute size found in any group, the proportionate increase of egg-size is about the same whether the group starts from a very low or a very high absolute size (*cf.* Oscines, Columbæ and Limicolæ as against Anseres and Otididæ).

This recalls the interesting facts recorded by Champy (1923, pp. 151 *seq.*) in regard to the heterogonically-growing organs of various insects.

It remains to see whether the curves throw any light upon the changing relation of egg-weight to body-weight. So far I have been unable to find any single satisfactory expression. One suggestion is, however, possible. When curves are plotted thus, logarithmically, the tangent of the angle of slope gives the power  $k$  in the expression  $y = bx^k$ . If  $k = 1$ , and the curve slopes at  $45^\circ$ , we have a direct linear proportion. If  $k = \frac{2}{3}$  (when the curve will slope at about  $34^\circ$ ), then if  $x$  and  $y$  are weights of X and Y respectively,  $y$  is a function of the *surface* of X. It is noticeable that for these curves  $k$  is always between 1 and  $\frac{2}{3}$ . Not only this, but at or near the start of the curves,  $k$  is often quite close to 1 (about .9 to .95) and at the close it is often quite close to  $\frac{2}{3}$  (about .7). It may be suggested that the linear relation, the weight of the egg increasing in direct proportion to the weight of the bird, would be that which would be most advantageous; but that physical difficulties stand in the way of its realization. The egg is an enormous cell, and each successive increase of size will presumably be achieved with proportionately greater difficulty. Nourishment for the growth of the egg must come through the egg's surface; and therefore an increase proportional to surface-increase may give the lower limiting value for our curve. On the curve for totals (Pl. 26) the slope at the start is almost exactly 1.0, at the close almost exactly  $\frac{2}{3}$ .

It is thus suggested that the shape of the curves may be due to the interaction of two sets of agencies—the biological advantage of securing an egg retaining its proportional weight; and the physiological difficulty of

\* The lowest point for Psittaci depends on the measurements of only one species, and is here disregarded.



increasing egg-weight more quickly than in proportion to the existing surface.

Whether this be the correct interpretation or no, the general regularity of the curves is of considerable interest. Biologists should be extremely grateful to Dr. Heinroth for his laborious accumulation of data, and should attempt to extend and improve on those data. Accurate weight-measurements should be as much a matter of systematic routine as accurate length-measurements or colour-descriptions.

Another interesting point is this. In some groups, there is an indication that the curve for the group is really a compound curve, formed by the combination of two separate curves, one for the smaller, the other for the larger members of the group. This is well shown in *Anseres* (Pl. 29). The smaller forms start at a body-weight of about 300 g. The curve goes up steeply at first, but flattens in a very regular manner to about 2,000 g. body-weight. From about 3,000 g. body-weight a new sharp rise in the curve is seen, flattening again later; and the slope for the part between 2,000 and 3,000 g. body-weight can be best interpreted as a region of overlap (see Pl. 28). If two separate curves are really thus combined, it would indicate that the phenomenon already seen, of each group appearing to have a typical curve of its own, might be extended to sub-groups within the groups chosen. In the *Anseres* the geese and especially swans would have a different curve from the ducks, starting at a much higher absolute body-weight. The *Columbæ* seem to show a similar phenomenon; in the *Laridæ* too, the curve ascends at the end. The same appears to hold good for the separate families of the grebes and divers within the group *Colymbiformes*, as shown on Pl. 29. The numbers of species, however, are much smaller than in the *Anseres*, only five in *Podicipididæ* and three in *Colymbidæ*.

It is clear, however, that before we can regard this last general point as established, we shall require more accurate and especially more extensive data. Similar data with regard to other organs and other groups would obviously be of great interest. Unfortunately, biologists have not usually troubled to collect the data, and the facts are meagre. One of the few considerable bodies of accurate measurements refers to the brain-weight of various vertebrates, notably mammals. This has been recently summarized and discussed by Dubois (1922) and by Lapicque (1922). The percentage weight of the brain decreases with the absolute weight of the body. Dubois has shown that the relation of brain-weight ( $y$ ) to body-weight ( $x$ ) in different species of various mammalian orders is represented by the expression  $y = bx^k$ .  $k$  for all mammal groups is between 0.54 and 0.58, and  $b$  is a constant which differs in different groups (2.8 in man, 0.7 in anthropoids, 0.4 to 0.5 in monkeys, 0.31–0.34 in *Felidæ*, 0.07 in *Muridæ*: in aquatic forms—seals, cetacea— $b$  is abnormally high owing to excessively thick myelin sheaths). The mean value of 0.56 for  $k$  also applies to birds and apparently to other vertebrates. However, *within a single species* (i.e. for

large and small individuals)  $k$  has a much lower value (0.22–0.23 in man, 0.20 in squirrels). This appears to hold even for large domestic varieties, when compared with wild forms (rabbits) or with small domestic varieties (dogs, where it is 0.25).  $b$  is the same for the two sexes in man, on the assumption that  $k$  is to be taken as 0.56 for the two sexual types.

Lapicque points out (1922, p. 89) that theoretically we might suppose that  $k$  should be  $\geq \frac{2}{3}$ ; however, certain peripheral sensory areas increase at a much lower rate than the surface, which brings about the reduction of  $k$  to the observed figure of 0.56. Lapicque and Giroud (1923 *a* & *b*) have also provided us with interesting facts regarding other parts of the nervous system. The mean area of the cross-section of the spinal cord varies in different species according to a similar expression, but with  $k=0.25$ . The mean number of fibres in the sciatic nerve increases from mouse to rat according to a similar expression, but with  $k=0.42$  (1923 *a*). As between small and large breeds of dogs, however,  $k$  (for spinal nerves) is only 0.18. Further, the value of  $k$  is considerably lower for the sensory fibres of the dorsal root than for the motor fibres of the ventral root (1923 *b*).

Lapicque has also calculated that the surface of the retina of the eye increases as between different species only about half as fast as the general body surface, and in different breeds of one species (dogs) again only about half as fast as between different species. It would be of great interest to obtain data on relative egg-size in breeds of different sizes within one species, *e. g.* fowl, duck.

Klatt (1919) has stressed the importance of absolute body-size in studying the relative size of organs, and also pointed out the value of the simple formula which Lapicque, Dubois, and myself have all arrived at, when considering the relative size of a part. He finds the value of  $k$  for the heart-weight of homoiothermic vertebrates to be 0.83, and has an interesting discussion of the various values found for  $b$ .

#### SUMMARY.

1. Heinroth's important data on the body-weight and egg-weight of 432 species of birds have been re-examined, and the figures for ten selected groups, and for the total of all groups, presented in simplified graphic form. The body-weights range from about 2 g. to 90 kg., the egg-weights from about 0.3 g. to over 1 kg. The relative egg-weight decreases from 12.2 per cent. in the first class to 1.8 per cent. in that of highest body-weight.

2. As already shown by Heinroth, relative egg-weight decreases as absolute body-weight decreases.

3. The relation between egg-weight ( $y$ ) and body-weight ( $x$ ) within any group of birds can apparently be expressed by an equation of the form  $y=bx^k$ . However, while  $k$  approximates to 1.0 for small values of  $x$ , it gradually decreases with increasing body-weight, and the limiting value for large values of  $x$  appears to be about  $\frac{2}{3}$ .

4. This may indicate that two antagonistic processes are at work in deciding relative egg-size, one (possibly biological advantage in the struggle for existence) favouring growth of egg-weight in linear proportion to body-weight; the other (possibly the physiological difficulty of increasing the bulk of the already enormous egg-cell) restricting growth of egg-weight to a linear proportion to surface (of body or egg).

5. As is well known, different groups of birds show different relative egg-weights. It is shown that the difference between groups in this respect remains approximately constant through the whole range of body-size. Special conditions of life, such as nidicolous and naked condition of young (*e.g.* Oscines), and, still more notably, reproductive parasitism on smaller species (some cuckoos) are correlated with special values for the relative egg-weight.

6. The curves for each group are on the whole similar in shape whether the group comprises only small or only large forms. Thus between the same absolute body-weights, egg-weight increases much less rapidly in the larger members of a group of low mean size than in the smaller members of a group of high mean size (*e.g.* Oscines *versus* Columbæ; Oscines, Columbæ and Limicolæ *versus* Anseres and Otididæ).

7. There are indications in some groups of the superposition of two (or more?) curves of the above mentioned type, one for the smaller, the other for the larger forms within the group (Anseres, Colymbiformes, etc.).

8. The importance of accurate weight-measurements for various problems of general biology is emphasized.

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TABLE I.

All Heinroth's data grouped into 16 classes by body-weight.

Class.	Range of body-wt. (g)	Number of species.	Mean body-wt. (g)	Mean egg-wt. (g)	1000 ( $\frac{\text{egg-wt.}}{\text{body-wt.}}$ )
<i>Carinatae</i> (excluding parasitic Cuculidæ, as highly aberrant).					
1	2-4	2	2.63	0.32	121.7
2	-7	3	6.00	0.74	123.3
3	-10	8	8.31	1.04	125.2
4	-20	19	14.7	1.63	110.9
5	-27	15	22.7	2.64	116.3
6	-35	14	31.4	3.39	108.0
7	-80	52	53.8	6.88	118.6
8	-180	51	122.6	12.72	103.7
9	-400	47	278.8	21.37	76.6
10	-600	41	492.8	33.23	67.4
11	-1500	89	967.9	53.39	60.3
12	-2600	33	2052	90.95	44.4
13	-8000	41	4173	149.0	35.7
14	-12000	6	9417	256.7	27.3
15	-35000	2	23500	460.0	19.6
<i>Ratite</i> (excluding <i>Apteryx</i> as highly aberrant).					
16	20000 to 90000	4	45750	806.3	17.6
Total ..... 427					

For the purposes of Pl. 25, these have been regrouped. Classes 1, 2, 3, 4 & 5 have been combined as Class A; Classes 7 & 8 as Class B. Classes 15 & 16 have been omitted on Pl. 25, but inserted, separately, and grouped together (=Class C) in Pl. 26.

A	2-27	47	15.19	1.74	114.6
B	35-180	103	87.9	9.52	108.3
C	12000 to 90000	6	38667	691.0	17.9

TABLE II.—Heinroth's data, main groups only, arranged by body-weight classes within groups.

<i>Passeriformes. Oscines (83 species).</i>				<i>Falconiformes (32 spp.).</i>			
Class limits. (g)	No. of species.	Mean body-wt. (g)	Mean egg-wt. (g)	Class limits. (g)	No. of species.	Mean body-wt. (g)	Mean egg-wt. (g)
5- < 7	3	6.0	0.74	< 100	1	95.0	15.5
10	8	8.0	1.04	200	—	—	—
14	7	11.7	1.30	350	4	225	21.3
20	10	17.1	1.92	600	2	485	42.5
27	12	22.8	2.35	1000	4	775	52.3
35	6	30.0	3.08	1600	6	1222	69.0
45	8	37.9	3.41	4750	9	2811	121.3
55	4	51.6	4.23	12000	6	7335	212.8
80	8	67.7	6.02	<i>Columbae (22 spp.).</i>			
135	4	97.5	7.13	< 40	1	55	2.4
180	3	168.3	10.27	80	3	59	4.3
275	4	206.3	12.05	150	4	111.8	7.8
600	4	396.3	16.15	250	3	195.0	9.0
1400	1	1300.0	30.00	350	2	300	16.5
1800	1	1650.0	34.00	475	2	400	20.5
<i>Limicolæ (32 spp.).</i>				650	6	517	22.0
> 20-30	3	26.7	5.70	1300	—	—	—
50	5	43.6	9.37	2600	1	2000	50.0
60	5	59.0	12.1	<i>Strigæ (16 spp.).</i>			
130	7	109.3	17.7	< 80	2	75	9.0
180	—	—	—	125	2	110	12.3
275	7	212.1	28.6	200	2	182.5	15.0
< 600	2	475.0	47.5	400	4	320	21.4
900	3	750.0	54.3	800	2	630	43.5
<i>Otididæ (4 spp.).</i>				1500	1	1300	55.0
< 1000	1	870	38.5	3000	3	2283	73.3
2500	2	1500	70.0	<i>Psittaci (18 spp.).</i>			
4500	1	4000	130.0	< 15	1	13.0	1.50
<i>Laridæ (14 spp.).</i>				32	3	28.3	2.47
> 35-60	2	50.0	10.5	45	2	37.0	2.63
135	4	117.5	23.1	90	—	—	—
300	1	250.0	38.0	140	2	117.5	7.00
900	4	525.0	52.5	180	2	155	8.15
1600	3	1300.0	108.0	350	—	—	—
<i>Anseres (59 spp.).</i>				550	5	405	18.3
300- < 400	2	340.0	26.5	1100	3	833	29.0
600	5	500.0	39.2	<i>Cuculidæ.</i>			
1000	20	737.8	54.3	<i>Cuculus canorus</i>	100	3.0	
1700	13	1296.2	83.4	<i>C. canorus</i> and 3			
2700	7	2050.0	108.1	other parasitic			
4700	7	3428.6	158.7	species; mean ..	103	3.95	
7000	3	5000.0	243.3	<i>Ratitæ.</i>			
10000	2	8750.0	340.0	<i>Apteryx</i> sp. ....	2500 (±)	455	
<i>Galli (34 spp.).</i>				<i>Rhea, Casuarii,</i>			
45- < 65	2	52.5	5.08	<i>Dromæus,</i>			
125	3	100.0	8.17	<i>Struthio</i> ; mean ..	45750	806.3	
175	2	160.0	10.00				
575	10	494.5	25.10				
950	3	766.7	28.5				
1550	8	1198.8	45.3				
3000	3	1991.7	55.7				
4000	3	3418.7	92.0				

## EXPLANATION OF THE PLATES

## PLATE 25.

Relation of egg-weight to body-weight in birds, from Heinroth's data. Ten groups are plotted separately, as well as the data from Heinroth's totals. Egg-weight and body-weight are both plotted logarithmically.

## PLATE 26.

Relation between egg-weight and body-weight in birds, totals from all Heinroth's data, plotted logarithmically.  $\odot$  = Carinatae (15 classes);  $\times$  = Ratitae (excluding *Apteryx*);  $\bigcirc$  = last point of Carinatae combined with all Ratitae (excluding *Apteryx* which is plotted separately). The lower set of points represents the continuation of the upper. The scales for the upper points are on the left and top; those for the lower set on the right and bottom. The two firm lines are drawn to fit the expressions  $y = bx^1$  (upper set of points) and  $y = bx^{\frac{1}{2}}$  (lower set). The dotted line indicates the intermediate slope.

## PLATE 27.

Right (continuous line). All data for Oscines (Passeres) on absolute scale.

Left (dotted line), the same on a larger scale, up to body-weight = 100 g. (Classes 8 and 9 of the right-hand curve have been grouped together.)

## PLATE 28.

This plate shows the intersection of the egg-weight curves for groups with different minimum size.

$\odot$  = Limicolae (all Heinroth's data).

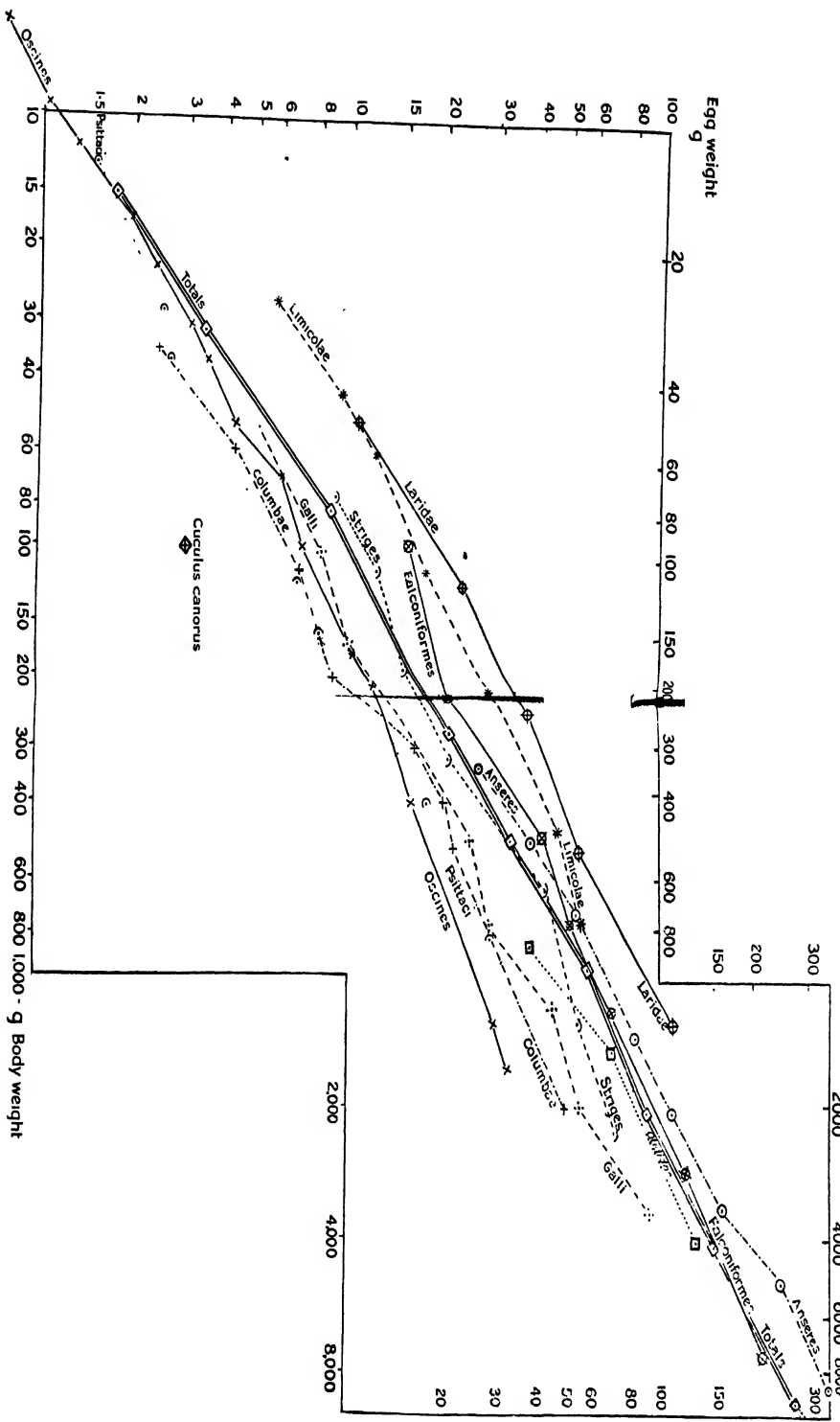
$+$  = Falconiformes, smaller body-size classes (excluding lowest point, one specimen only).

$\times$  = Anseres, three lowest body-size classes.

## PLATE 29.

This plate shows the apparent compound nature of curves for egg-weight in Anseres  $\bigcirc$  and Colymbiformes  $+$ .

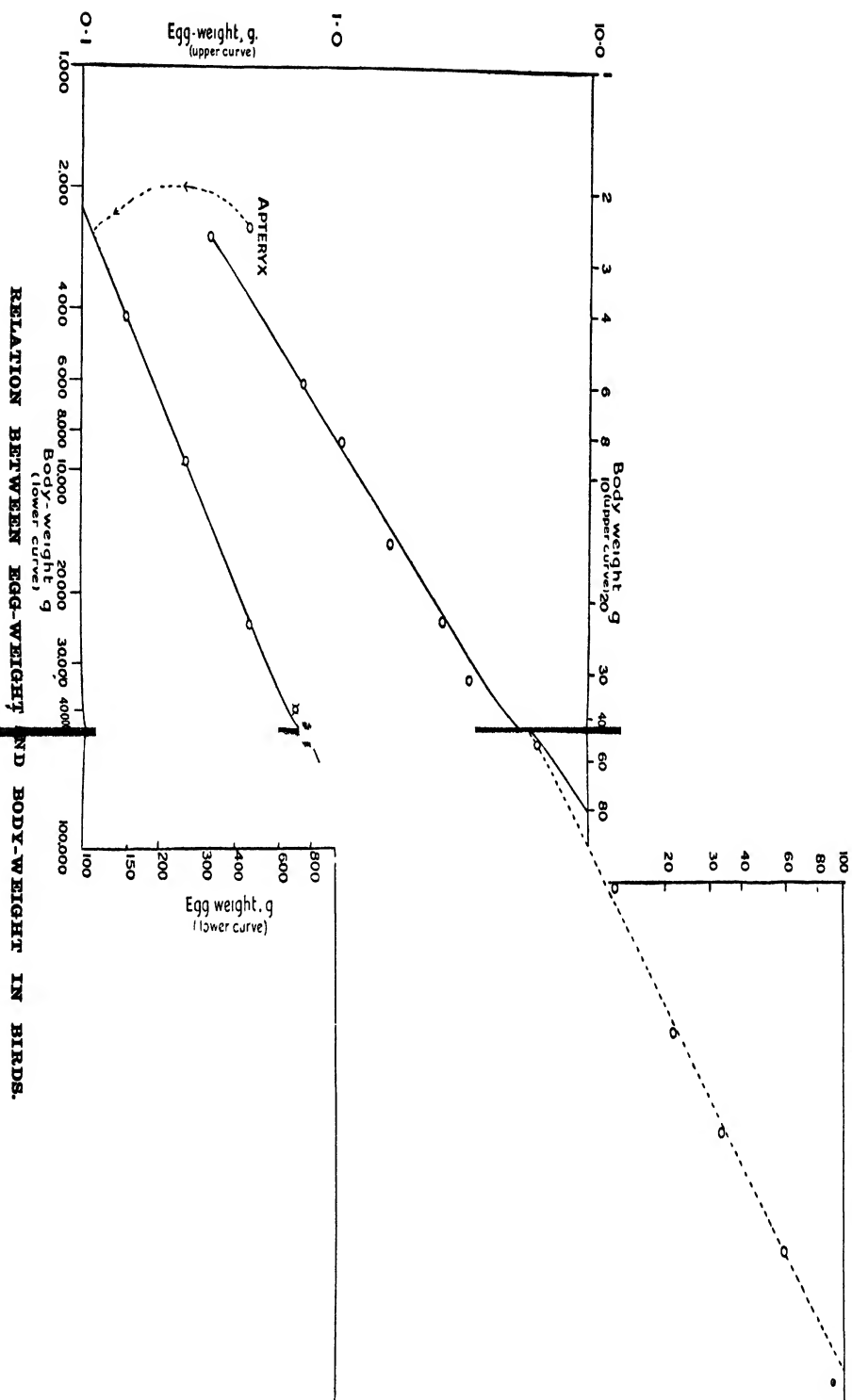




RELATION BETWEEN EGG-WEIGHT AND BODY-WEIGHT IN BIRDS.

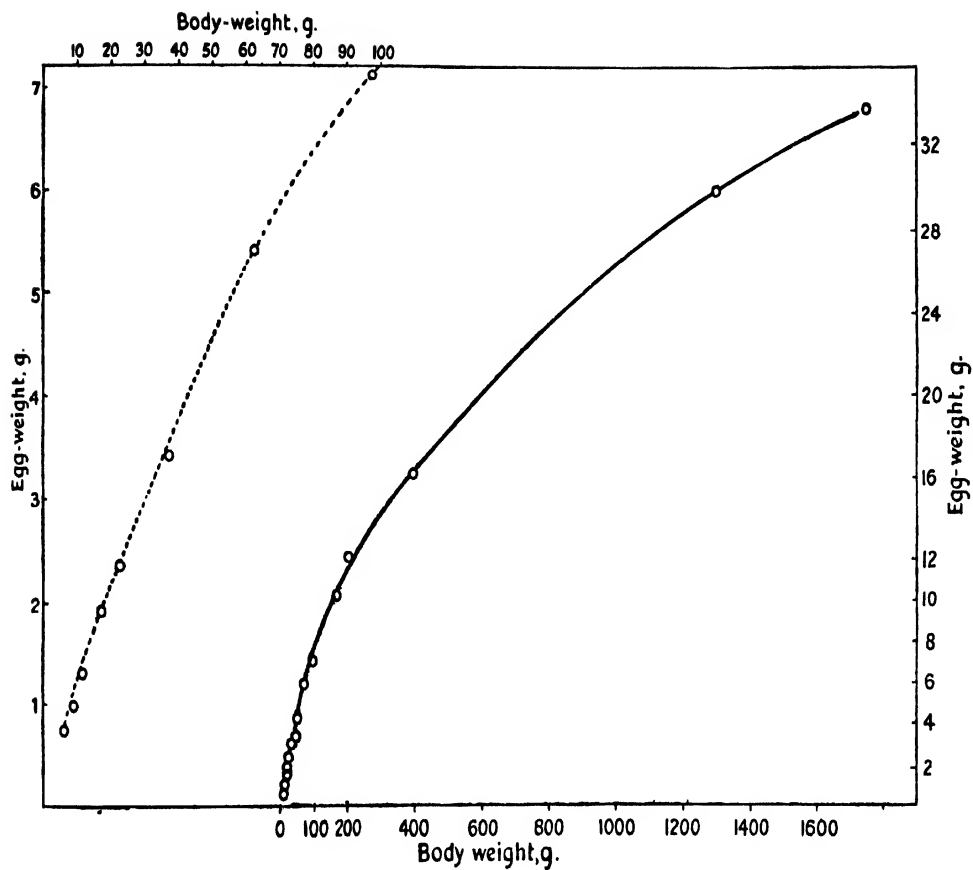






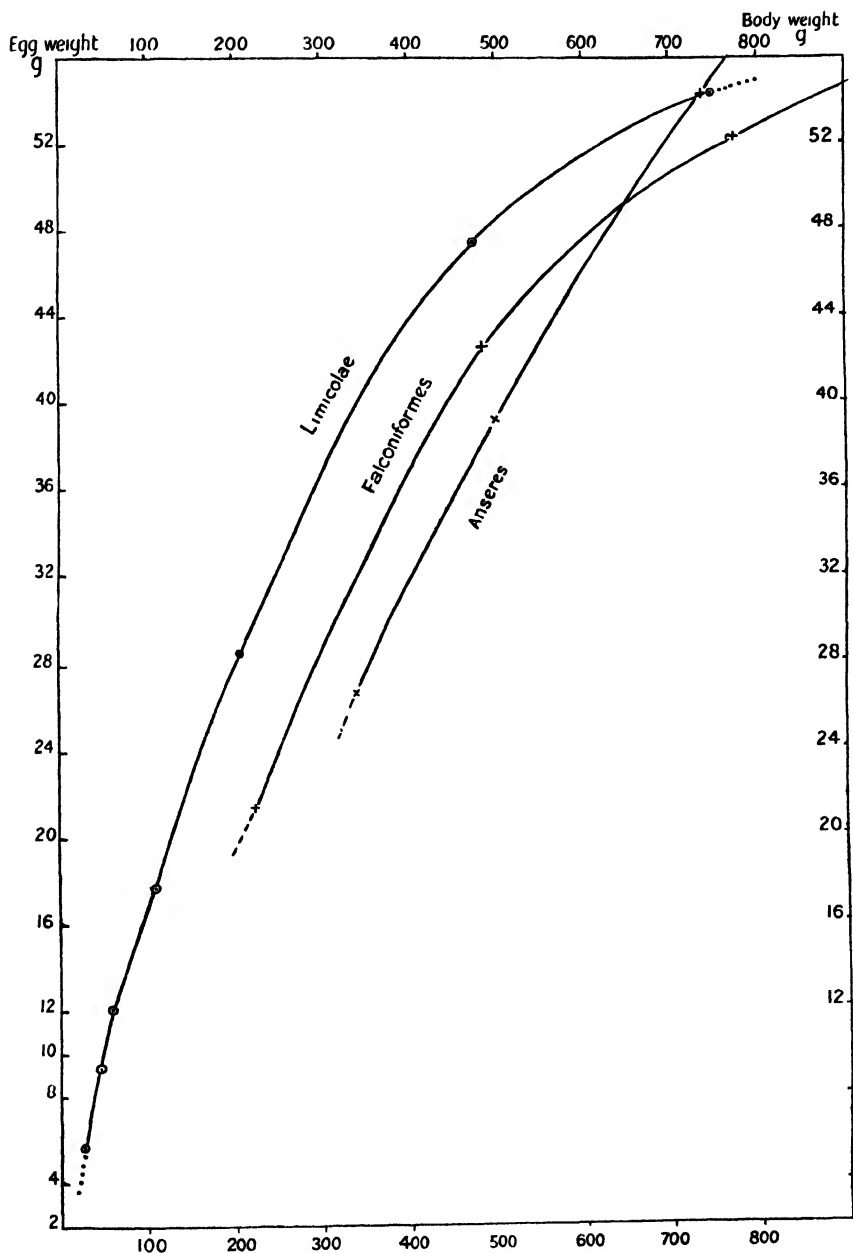
RELATION BETWEEN EGG-WEIGHT AND BODY-WEIGHT IN BIRDS.





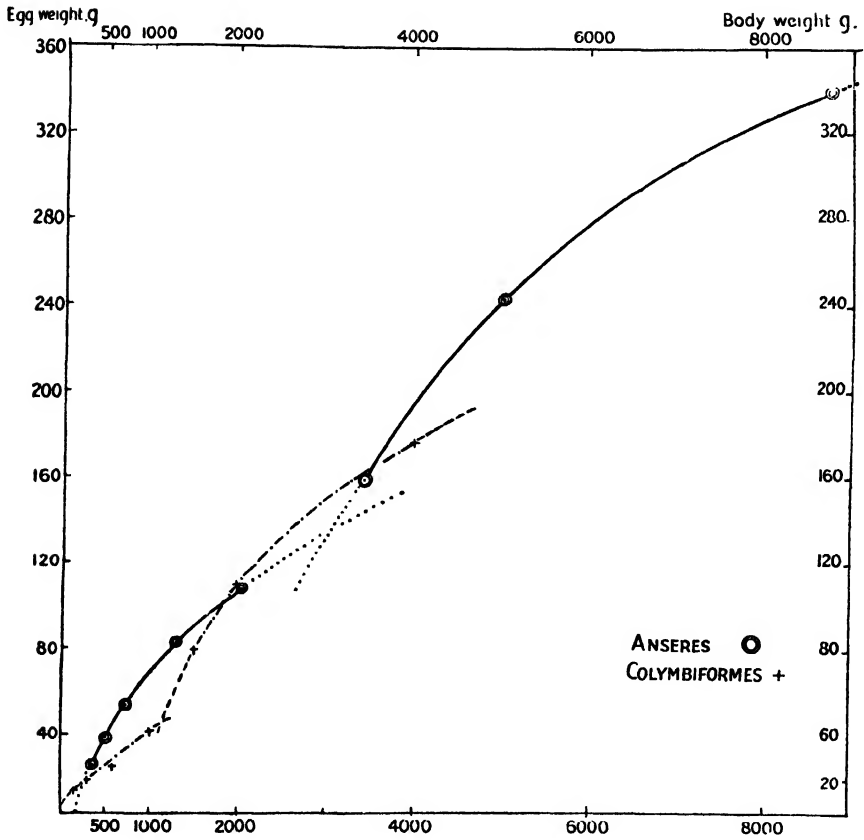
RELATION BETWEEN EGG-WEIGHT AND BODY-WEIGHT IN BIRDS.





RELATION BETWEEN EGG-WEIGHT AND BODY-WEIGHT IN BIRDS.





RELATION BETWEEN EGG-WEIGHT AND BODY-WEIGHT IN BIRDS.





On the Occurrence of Intermediates in *Aphis rumicis* L. and their Relation to the Alate and Apterous Viviparous Females. By J. DAVIDSON, D.Sc., F.L.S., Entomological Department, Rothamsted Experimental Station, Harpenden.

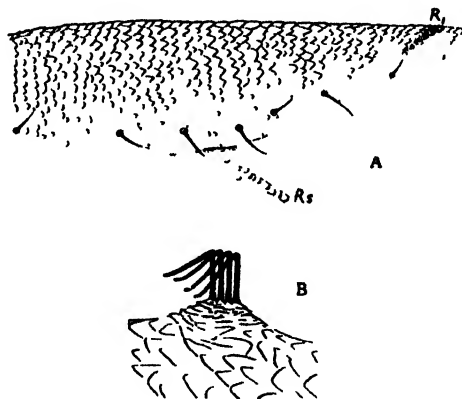
(With 5 Text-figures.)\*

[Read 3rd March, 1927.]

### I. INTRODUCTION.

IN most members of the family Aphididæ (excepting the tribe Callipterini) apterous, viviparous females develop in one or more of the parthenogenetic generations. The alate viviparous females are closely associated with the habits of migration and ensure distribution of the species. The alate forms are generally considered as representing the more primitive condition, the apterous forms having arisen later.

FIG. 1.



Normal alate v. female.

A. Pterostigma (distal portion),  $\times 95$ .  $R_1$ . Radius vein;  $R_s$ . Radial sector.

B. Wing coupling hooklets on hind-wing,  $\times 370$ .

(For other details regarding the adult alate and apterous viviparous females, see Davidson, J., 1921. Bull. Ent. Res. xii. pp. 81-89.)

In previous papers (1921 and 1926) the writer has shown the relationships existing between the various polymorphic forms of *A. rumicis*, but the question of the occurrence of intermediates was not dealt with. The present paper deals with the parthenogenetic intermediates (forms possessing morphological features which place them as intermediate between alate and

\* The cost of the figures has been met from the Westwood Fund.

apterous viviparous females), which have been recorded in the colonies during a long series of rearing experiments with a single strain of this species on Longpod broad beans. Three types of intermediates obtained are here described, and observations are recorded on the relationship of the intermediates to other polymorphic forms in the same generation. Intermediate forms have been recorded in several species of Aphides (*vide* Baker & Turner, 1915, 1916), but, so far as I am aware, no account has been given regarding the genetic relationships of these forms.

## II. OBSERVATIONS ON THE INTERMEDIATES RECORDED IN THE COLONIES.

Twenty-one individuals have been recorded, and the history of these intermediates in the lines of reared generations is known. They were adult on or about the dates shown in the table below. Doubtless others developed which were not recorded, as many colonies were not critically examined for these forms. This was especially the case with many of the large summer colonies.

Expt. Plant No. (Colony).	Date of record.	No. of intermediates present in the colony.	Reference No. to Intermediates.
A 13	9. xii. 20.	1	1
A 39	23. iv. 21.	4	2-5
A 42	7. v. 21.	1	6
B 16	6. x. 21.	1	7
B 16	13. x. 21.	1	8
B 17	27. x. 21.	1	9
B 19	15. xi. 21.	5	10-14
B 22	10. ii. 22.	1	15
B 63	12. iii. 23.	1	16
B 85	29. x. 23.	2	17-18
G 3	8. ii. 26.	2	19-20
G	3. vi. 26.	1	21

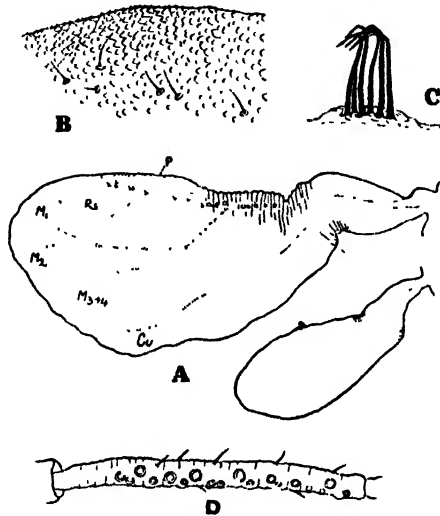
The intermediates vary in appearance, indicating by their structure a greater or less degree of approximation to the apterous condition. Three types are described and figured which will serve to illustrate their general features.

### *Intermediate type A.* (Fig. 2, A-D.)

Morphologically this type approximates in many respects to the alate female but differs in detail with regard to the wings and the development of the

mesothorax, as well as in the character of the ocelli and antennal sensoria \*. It suggests an alate form in which, owing to some physiological disturbance during development, the wings and associated structures have failed to develop completely. I have seen this condition in other species and other cases in *A. rumicis*, and considered it as an accidental failure on the part of the insect to complete its development. It appears to me, however, that one

FIG. 2.



Intermediate type A.

A. Imperfect wings showing traces of venation,  $\times 20$ .

B. Portion of Pterostigmatic area,  $\times 95$ . C. Hooklets of hind-wing,  $\times 370$ .

D. Antenna, segt. 3.

Cu. Cubitus vein; M<sub>1</sub>, etc. Media; P. Pterostigma; Rs. Radial sector.

might rightly consider it as an intermediate type, since it cannot function as an alate individual. The wings are useless as organs of flight, being delicate membranous sacs, possessing only a faintly developed venation. There is a well-defined row of setae on the anterior wing, along the region of the Radius vein, and the annular bases of the absent setae are seen along the region of

\* The antennal sensoria are of two kinds, which may be defined as (a) *permanent sensoria* of which one is situated sub-apically on segment 5 and another on the proximal portion of segment 6. These well-developed organs are present in the adult sexual and parthenogenetic forms, being present on the 4th and 5th segment respectively in the case of the fundatrix. (b) *secondary sensoria*, a varying number of which develop on the 3rd, and occasionally a few on the 4th segment in the alate parthenogenetic female, and on the 3rd, 4th, and 5th segments in the alate male. They are not present in the apterous viviparous female nor the sexual female. In the present paper where the antennal sensoria are mentioned, it is this latter type which is meant.

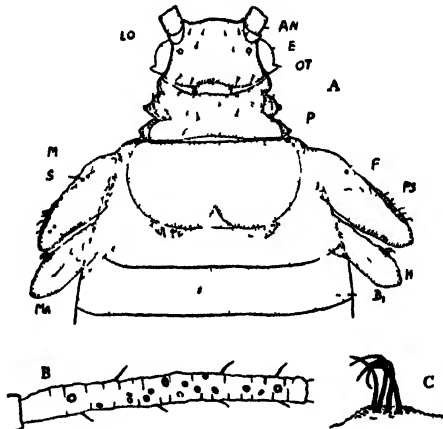
the composite main vein. The stigmatic area is irregularly defined (compare with fig. 1 A), and the plate-like thickening of the chitin in this area is less pronounced. The inner marginal fold, which in the normal wing receives the hooklets of the hind-wing, is not developed.

The hind-wing exhibits only a faint trace of the normal venation and the wing-coupling hooklets are slender and irregular, being apparently unsuited for their original function (compare with fig. 1 B).

The mesothorax is fairly well developed, but compared with the normal alate form, the chitin is much thinner and the sclerites are not so well defined.

Three ocelli are present but they are reduced in size and the sensoria, compared with the alate v. female, are more irregular, several being quite small.

FIG. 3.



Intermediate type B.

A Dorsal view,  $\times 40$ . B. Antenna, segt. 3,  $\times 95$ . C. Hooklets on hind-wing rudiments,  $\times 370$ .

An. Antenna; B<sub>1</sub>. Abdominal segt.; E. Eyes; F. Rudimentary fore-wing; H. Rudimentary hind-wing; Lo. Lateral ocelli; M. Mesothorax; Ma. Metathorax; OT. Ocular tubercle; Ps. Pterostigma; S. Annular bases of setae similar to those found along the composite main vein in alate v. female.

*Intermediate type B.* (Fig. 3, A-C.)

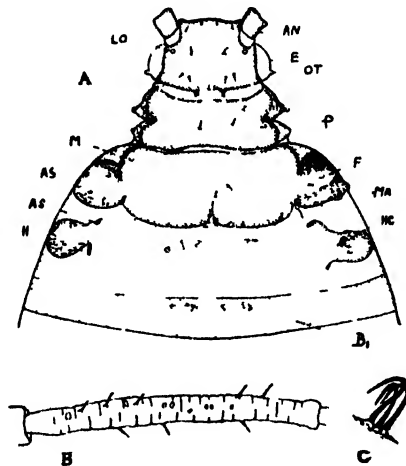
This type, which represents the form more commonly found, indicates a further advance to the apterous condition. The mesothorax is much less chitinized, and with the exception of a somewhat irregularly defined, darker, scutellar area, the thoracic plates are not evident. The wings are represented by two pairs of lobe-like evaginations from the meso- and meta-thorax, which are functionless wing rudiments. The lobes on the two sides may vary considerably even in the same individual. Along the costal margin of the anterior lobe, towards the apex, the border is irregularly thickened and bears

five or six stout setæ. The annular bases of other setæ are also seen. This area represents the Pterostigma of the normal fore-wing. No indication of the inner marginal fold is seen.

On the costal margin of the posterior lobe, towards the apex, a tubercle-like thickening of the chitin bears four or five stout, irregular bristles, which represent the wing-coupling hooklets of the normal hind-wing. From their position with regard to the anterior lobe, it is clear that they cannot function as such. The median ocellus is absent and the two lateral ocelli are considerably reduced. The antennal sensoria are also much reduced.

This type of intermediate is readily distinguished from the 4th instar nymph of the alate female, which also possesses two pairs of prominent thoracic lobes or wing-cases. In the latter the wing-cases are distinctive, regular structures, in which the folded wings can be seen when the specimen is mounted in glycerine; moreover, the mesothoracic sclerites are fairly well outlined, and the cauda is comparatively short and rounded, whereas in the intermediates it is of the normal adult type.

FIG. 4.



Intermediate type C.

A. Dorsal view,  $\times 40$ . B. Antenna, segt. 3,  $\times 95$ . C Hooklets on rudimentary hind-wings,  $\times 370$ .

As. Axillary sclerites; Hc. Hooklets on rudimentary hind-wing.

Other lettering as in fig. 3.

*Intermediate type C.* (Fig. 4, A-C.)

In this type we have a form which closely resembles the apterous v. female in general body contour, and it is only the slightly pronounced shoulders of the mesothorax and the greatly reduced lateral ocelli which give the clue to its intermediate character.

The thorax is not markedly differentiated from the rest of the body, although a slightly darker pigmentation of the chitin faintly indicates the scutellar area of the mesothorax.

There are no external wing rudiments, but on careful examination of the cleared specimen, these were found to be actually inside the thorax, and traces of the axillary sclerites were also visible; the wing rudiments show clearly through the chitin of the thorax, owing to the darker pigmentation of their chitinous walls; on the right posterior lobe, the bristles representing the hooklets of the hind-wing are clearly visible.

The lateral ocelli are greatly reduced and the median ocellus is absent. The antennal sensoria are represented by a few faint irregular rings. From this type it is but a small step to the normal apterous v. female.

### III. THE HISTORY OF THE RECORDED INTERMEDIATES.

The details regarding the intermediates listed in the table on p. 468, particularly with reference to their immediate relations of the same generation, are given below: the history of Nos. 1-15 is shown graphically in fig. 5.

#### *Intermediate No. 1.*

The apterous v. female which produced this intermediate was adult about 29. x. 20 and isolated 23. xi. 20, having by that time produced only one or two young, the bean plant being poor and the temperature low; it produced three alate v. females, one apterous v. female, and the intermediate. The three alate females produced only sexual females, being alate sexuparae, and the apterous v. female produced alate sexuparae and one apterous v. female. The intermediate produced eleven alate v. females only. These latter were not tested out, but they were doubtless alate sexuparae. It will be seen therefore, by comparing the offspring of its apterous and alate relations, that this intermediate behaved as an apterous form.

#### *Intermediates Nos. 2-5.*

These four intermediates appeared at the end of April, in a colony which consisted of the offspring of five apterous v. females. The colony included a number of alate v. females and apterous v. females, the latter being in the majority, and in addition two males. The alate v. females were sexuparae. The apterous v. females tested out produced alate and apterous v. females of which the alate females produced only apterous v. females, being alate virginiparae\*. Two of the intermediates were tested out, and their offspring

\* The alate v. females which appeared in the colonies between October and April were generally found to be sexuparae. During May both sexuparae and virginiparae developed, but from about end of May to September only alate virginiparae developed. This aspect of the experiments will be dealt with in another paper.

consisted of one intermediate (No. 6) and several apterous v. females, but no sexual females were produced. In comparison with the alate and apterous individuals of the same generation, these intermediates behaved therefore as apterous v. females.

*Intermediate No. 6.*

This intermediate was produced by one of the previous intermediates, its sisters and cousins being apterous v. females.

FIG. 5.

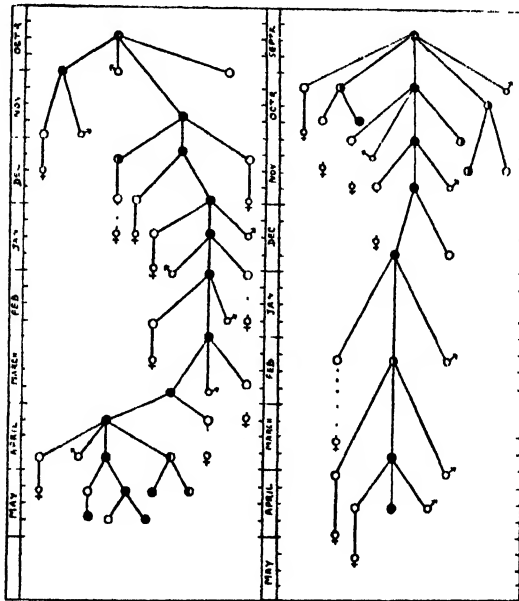


Diagram showing the occurrence of intermediates in the colonies of various generations in two parthenogenetic lines of *Aphis rumicis* L. The symbols show the different forms present in the colonies, and their positions with reference to imaginary parallel lines joining the divisions of the monthly periods, give the approximate dates they become adult. Each symbol represents more than one individual, except where stated otherwise in the text. On the left of the chart, intermediates Nos. 1-6 are shown and on the right Nos. 7-15. For other details see text.

● = apterous viviparous females. ○ = alate viviparous females (sexuparae, where shown as producing sexual females, virginiparae where shown as giving rise to apterous v. females). ◐ Intermediates.

♀. Sexual females (produced by sexuparae); in those cases joined by a dotted line to the sexuparae, the individuals were not reared, but the evidence indicates that the alate forms were sexuparae.

♂. Males (winged).



*Intermediates Nos. 7, 8.*

These appeared in a colony of parthenogenetic line started from a fundatrix on 25.iii.21. The colony was produced by six apterous v. females. One intermediate was adult about 6.x.21, and the other about 13.xi.21. The other members of the colony consisted of a number of alate v. females (sexuparæ), a few apterous v. females, and a few males. Intermediate No. 7 produced several alate v. females and a few apterous v. females. The alate forms were not tested out but were presumably sexuparæ. Intermediate No. 8 produced 11 alate v. females, which were not tested out (? sexuparæ) and five intermediates (Nos. 10-14).

*Intermediate No. 9.*

This intermediate appeared at the end of October 1921, in a colony which was produced by four apterous v. females. The other members of the colony were mostly alate v. females (sexuparæ) together with a few apterous v. females and a few males.

*Intermediates Nos. 10-14.*

As noted above, these forms, which developed about the middle of November 1921, were the direct offspring of intermediate No. 8, their sisters being alate v. females, presumably sexuparæ.

*Intermediate No. 15.*

This intermediate appeared early in February 1922, in a colony produced by two apterous v. females. The other members of the colony were seven alate v. females (sexuparæ) and one immature male. No apterous v. females were produced, and the continuation of the line therefore depended on the offspring produced by this intermediate. Development of the aphides during the period was slow, owing to the low temperature in the glasshouse. The intermediate produced several alate v. females, three males, and one apterous v. female. These alate offspring produced only sexual females, being sexuparæ; the offspring of the apterous v. female were alate sexuparæ, one apterous v. female, and three males. This intermediate therefore behaved as an apterous form.

*Intermediate No. 16.*

This individual appeared (12.iii.23) in a colony originated by a mixed infection of alate v. females and apterous v. females (transferred on 8.ii.23). It was evidently produced by one of the apterous v. females, since the alate forms produced only sexual females, being sexuparæ. On 12.iii.23 the colony consisted of 12 alate sexuparæ, the intermediate and 30 sexual females; no apterous v. females were present. It seems evident that this intermediate may be considered as an alate form which has tended to the apterous condition.

*Intermediates Nos. 17-18.*

These two intermediates appeared 29. x. 23, in a colony which consisted of the offspring of four apterous v. females, transferred 8. x. 23. Development of the aphides was slow. By 20 xi. 23 these four apterous females had produced 25 alate v. females, 9 males, and the 2 intermediates, but no apterous v. females developed in the colony.

*Intermediates Nos. 19-21.*

Intermediates Nos. 19 and 20 appeared 8. ii. 26 in a colony of a new line of the same strain of the aphid, which was commenced with one fundatrix in April 1925. The colony consisted of the offspring of three apterous v. females, which were transferred on 4. xii. 25 and produced 12 alate sexuparæ, 3 apterous v. females, and the 2 intermediates. The aphides were reared under comparatively low temperatures in a glasshouse and development was slow. Intermediate No. 21 appeared in a colony of the same line on 3. vi. 26.

## IV. GENERAL CONCLUSIONS.

The problems concerned with the occurrence of winged forms in Aphides have received the attention of several investigators, and it is proposed in the present paper only to discuss the question in relation to the significance of the intermediate forms.

From the numerous data obtained during the rearing experiments with *A. rumicis*, it is evident that alate virginiparæ tend to produce apterous v. females, although occasionally they may produce some alate forms. Alate sexuparæ in my experiments only produced sexual females (apterous).

Apterous viviparous females may produce only apterous v. females, especially in the early summer generations, but in general they tend to produce a mixed progeny of apterous v. females and a varying percentage of alate virginiparæ. In a normal environment this tendency to produce alate forms becomes more pronounced towards late summer, when, with the advent of the sexual phase, alate sexuparæ predominate, together with alate males. When parthenogenetic lines were continued throughout winter, under moderate temperature conditions, the dominating type in the offspring of apterous v. females was found to be alate sexuparæ with occasional alate males\*. From about the end of April, onwards throughout early summer there was a marked increase in the number of apterous v. females which developed in the colonies.

The apterous v. female cannot be considered as just an alate form which has lost its wings. Its occurrence and behaviour, especially as regards the type of offspring it tends to produce, fits well with the requirements of the

\* Apterous v. females may predominate under specially favourable conditions, *vide* Davidson, J., 'Science,' n. s., lix, April 18th, 1924, p. 864.

life-history, and there appears to be in nature a somewhat irregular, rhythmical appearance of alate and apterous individuals during the life-cycle of the species, the alate forms being developed at appropriate periods. This may be due to more or less established physiological conditions, which have evolved in association with seasonal changes and the migrating habit. Under experimental conditions, particularly by the influence of temperature and nutrition, this inherent tendency appears to be affected and an increase in apterous forms may be obtained.

The intermediates here recorded, in those cases where it was definitely known, were the offspring of apterous v. females, or of intermediates themselves, and were produced in colonies where there was a high tendency for alate forms to be produced. As regards the kind of offspring they produced, we have seen that the intermediates tested out behaved as apterous v. females. May we not then regard these intermediates as forms which, under conflicting physiological influences, are tending to the apterous condition, but the reaction is incomplete and wing rudiments and other associated external structures are not fully suppressed? The intermediate of the type C approximates extremely closely to the normal apterous v. female and suggests that in the latter individuals, the gene material which makes for wings and associated structures is suppressed or rendered inactive and these characters therefore remain dormant. This may conceivably be brought about by the influence of physiological factors in association with the apterous condition. One is led to the view therefore that the apterous condition is due to physiological causes, although its evolution has doubtless involved germinal changes.

In this respect the recent work of Ackerman (1926) is of interest. This author considers that "... wing production in the grain aphid (*Rhopalosiphum prunifoliae* Fitch) is dependent upon changes in the proportion or concentration of certain materials in the hæmolymph. . . ."

If we consider that the alate form represents the more primitive and stable condition in Aphides and that the apterous form has been secondarily evolved, it seems to the writer that the more logical statement of the problem should be: What factors induce the apterous condition in these insects?

There is considerable evidence to show that the proportion of apterous v. females which may develop in a colony—at any rate in certain generations—is influenced by environmental factors such as nutrition and temperature. The evidence is somewhat conflicting, which doubtless, to some extent, is due to the difficulty of repeating any set of environmental factors. It must not however be overlooked that in migrating species of Aphides there is evidently an inherent influence at work, which ensures the appearance of alate forms at appropriate periods of the life-cycle. This influence is doubtless stronger in some forms than in others, according to the degree of specialization and stability exhibited by the species, and we cannot expect

the same results from all species. In some Callipterini for example, the apterous condition appears not to have been developed. Similarly in some other species of Aphides the alate forms may be comparatively rare.

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Alcyonaria of the Abrolhos Islands, Western Australia. By LAURA THORPE, M.Sc. (Mrs. Hunter), formerly Assistant Lecturer in Zoology, University College of North Wales, Bangor. (Communicated by Prof. W. J. DAKIN, D.Sc., F.L.S., Derby Professor of Zoology in the University of Liverpool.)

(Percy Sladen Trust Expedition to the Abrolhos Islands.  
Under the leadership of Professor W. J. DAKIN, D.Sc., F.L.S.)

(PLATES 30-34.)

[Read 16th February, 1928.]

THE opportunity of examining this Collection of Alcyonaria was given me by Prof. Dakin, who made the collection in his second expedition to the Abrolhos Islands, West Australia, in 1915. I thank Prof. Dakin for this opportunity and also for his kindly help and criticism in the preparation of the paper. I have examined all the specimens, except two species of Pennatulacea, recently recorded by Prof. Hickson (1922). The work has been done in the Zoological Department, University College of North Wales, Bangor, and I am glad to have this opportunity of expressing my thanks to Prof. P. J. White for placing at my disposal all the resources of his laboratory, and more especially for his kindness during the progress of my work. My thanks are also due to Prof. S. J. Hickson for allowing me to examine the Alcyonaria in the Zoological Department, Manchester University, and for placing literature at my disposal; to Dr. Stuart Thomson, of Manchester University, for the loan of literature and help during my visits to the Manchester Laboratory; and to Mr. M. Burton, for the identification of the sponge *Clathria typica* (Carter).

Houtman's Abrolhos Islands lie about forty miles off the West Coast of Australia, on the edge of the Continental shelf, between 28° 15' and 29° latitude south. Prof. Dakin gives a detailed account of the history of the Islands in his report (1919) and points out the interesting coral formation of the islands, in which respect they differ from the neighbouring continental shelf. This coral growth is due to the tongue of warm water which extends down the coast of N.W. Australia, the tip reaching to the Abrolhos Islands. Here it is deflected away from the coast, thus leaving a strip of cold water between the islands and the mainland. The interest of the collection is therefore enhanced by the physical peculiarities of the situation from which it has been obtained, and it is important to discover whether the fauna is what one would expect at this latitude, or whether there is a distinctly tropical or subtropical bias. Reports on the Abrolhos Collections already published

reveal a strong tropical facies in all except the fish fauna, which is mainly composed of southern temperate forms and a few tropical species associated with coral reefs. The Alcyonaria also present a tropical facies, and, although a few temperate forms are present, a favourable comparison can be made with previous collections from coral reefs in the Indian Ocean. Our knowledge of Alcyonaria in the Indian Ocean has increased considerably since the publication of the Maldivé Reports in 1902, for collections have been recorded from all parts of the Indian Ocean except the southern area. The collection from S.W. Australia made by Michaelson and Hartmeyer was chiefly confined to Shark's Bay and the coast, and did not include the Abrolhos Islands. Thus, the present collection helps to complete our knowledge of Indian Ocean Alcyonaria and assists in determining the nature of the fauna of these coral islands.

Excluding the Pennatulacea, I have identified twenty-four species, eight of which are new, and nine of which are represented by new varieties. The representation of the main orders of Alcyonaria is as follows.

The Stolonifera appear to be rare, for only one genus, *Sarcodictyon*, is present. This genus appears for the first time in sub-tropical waters; previously it has been recorded only from the temperate seas of Great Britain and once from Adelaide. The absence of the genus *Clavularia* agrees with all the other Indian Ocean collections except that from Zanzibar. The genus *Tubipora*, usually one of the most abundant and luxuriant Alcyonaria on coral reefs, is not represented, and it is interesting to note that it is rare both at the Maldives and off the coast of Ceylon.

Representatives of the order Alcyonacea predominate, the majority being species of the family Nephthyidæ. The representation of the genus *Eunephthya* by three new species is worthy of note, since it is essentially a genus confined to temperate and cold waters, and is not typical of the warmer waters of the Indian Ocean. The nearly-related genus *Gersemia*, usually found in temperate waters, is represented by a single new species. The genera *Nephthya* and *Dendronephthya* are not so well represented as one might expect from their distribution in other Indian Ocean collections. It is noteworthy to find a new species of *Agaricoides*, especially in shallow waters. The genus was founded by Simpson (1906), who recorded one species from the Indian Ocean. Of the family Alcyoniidæ the two species of *Sarcophytum* are typically sub-tropical forms, but the presence of species of *Alcyonium* in these waters is worthy of note, especially the species *Alcyonium digitatum*, which has previously been recorded only from the temperate waters of the European coasts. The presence of four specimens of *Xenia* in the shore collection is interesting in that the family Xeniidæ has not been recorded previously from W. Australia, and *Xenia* is essentially a warm-water genus.

The order Gorgonacea is represented by only four specimens, three of which belong to the Juncellid group in the family Melitodidæ. This order is not so well represented as in the Maldivo collection, but was more abundant in the collections from Zanzibar. It is remarkable that no member of the Muriceidæ is present, for members of this family are typical of waters of lagoons of coral islands, as is well shown in the Maldivo collection. The absence of Primnoidæ and Dasygorgiidae is not surprising, species of these families being usually found in deep water.

The genus *Heliopora*, usually so abundant on other coral reefs of the Indian Ocean, is not represented by a single specimen.

According to Prof. Dakin, Alcyonaria are found in the lagoons and along the shore of these islands, but they do not predominate.

Apart from the distributional interest of this collection, it contains forms of phylogenetic and taxonomic importance. The stoloniferous creeping membrane in the specimens of *Xenia* provides a link between the orders Stolonifera and Alcyonacea. The three species of *Eumephthya* belong to the subgroup Alcyoniformes; they provide a link between the lobose members of the family Alcyoniidae with their well-developed cœnenchym and the tree-like forms of the Nephthytidae. One species, *E. whitei*, is quite lobose in appearance, whilst *E. brochi* is more dendritic. Also, the well-developed endodermal canal system in the canal-walls of these specimens is like that found in the Alcyonacea. An extra endodermal longitudinal canal system in the canal-walls in *E. brochi* calls for special attention. The new species of *Agaricoides* confirms Simpson's statement that the genus is closely connected with *Lemmalia*. The structure of the polyps in *Agaricoides* and their method of introversion is described in detail. The close resemblance of the specimens of *Alcyonium* in this collection has caused me to include a number of old species of *Alcyonium* as varieties in the old-established species, *Alcyonium sphærophorum*. The spicules found on *Sarcodictyon tropicale*, the first species of the genus to be recorded in warm waters, are of remarkable interest. The *Sarcodictyon* has incorporated in some way the silicious spicules of sponges, including some of the tetractinellid sponge upon which the specimen is creeping.

#### LIST OF SPECIES.

##### Order I. STOLONIFERA Hickson.

###### Family Clavulariidae.

*Sarcodictyon tropicale*, sp. n.

##### Order II. ALCYONACEA Verrill.

###### Family Kentidae.

*Xenia blumi* Schenck var. *pelsarti*, nov.

*Xenia ternatana* Schenck var. *littoralis*, nov.

*Xenia depressa* Kükth. var. *kükenthali*, nov.



Family **Alcyoniidæ.***Alcyonium sphaerophorum* Klunzinger var. *australiensis*, nov." " " var. *saxigena*, nov." " " var. *littoralis*, nov." *digitatum* Linn.*Sarcophytum trocheliophorum* Marenz. var. *australiensis*, nov." *acutangulum* (Marenz.) var. *occidentalis*, nov.*Sclerophytum durum* Pratt.Family **Nephthyidæ.***Dendronephthya nigrescens* Kükth. var. *abrollosa*, nov." *folifera* Pütter.*Nephthya complanata* Kükth." *glomerata* Th. & Simp.*Eunephthya abrollosa*, sp. n." *whitei*, sp. n." *brochi*, sp. n.*Gersemia australiensis*, sp. n.Subfamily **SIPHONOGORGINÆ.***Agaricoides simpsoni*, sp. n.Order III. **GORGONACEA.**Suborder **SCLERAXONIA.**Family **Melitodidæ.***Mopsella klunzingeri* Kükth." *hicksoni*, sp. n.*Acabaria dakini*, sp. n.Suborder **HOLAXONIA.**Family **Gorgonellidæ.***Scirpearia furcata* Hickson.Genus **SARCODICTYON** Forbes.

The two previously recorded species of the genus, *S. catenatum* and *S. agglomeratum*, have been found only in British seas except for a specimen of *S. catenatum* found off Adelaide at 20–35 fathoms and recorded by Hickson (1921). The specimen in the present collection is the second example of the order Stolonifera to be found in the Australian area and the first of the genus from sub-tropical waters.

There has been much discussion as to the affinities of the genus *Sarcodictyon*, of which only one species, *S. catenatum*, is at all well known. Milne-Edwards and Haime placed the genus as a member of the subfamily Cornularidæ, but Forbes (1853) maintained that it differed from *Alcyonium* merely in the ribbon-like stolon. Later writers place the genus close to *Clavularia* in the order Stolonifera, and Hickson in agreement with Sars united the genus with *Clavularia*. This was accepted by many, but later Hickson (1921) again separated them and drew attention to the fact that *C. dura* is the connecting-link, having hard walls like *Sarcodictyon*.

There has been much controversy as to the width of the ribbon-like stolon

and the arrangement of the zooids in the two species of *Sarcodictyon*; also as regards the texture of the surface and the colour.

Members of this genus are found growing attached to pieces of stone or shell, but the specimen in this collection appears as a network of strands over a somewhat flattened tetractinellid sponge. This habitat has much significance in the organization of the specimen.

*SARCODICTYON TROPICALE*, sp. n. (Pl. 30. figs. 1, 2; Pl. 33. figs. 1 and 8-12.)

*Locality*.—Dredged between Rat Group and Pelsart Group. One specimen.

The specimen is a narrow anastomosing ribbon, forming an irregular network on both surfaces of *Clathria typica* Carter, a flattened tetractinellid sponge, 13 × 5 cm. The sponge is dark grey, in striking contrast to the pale pink stolon of the *Sarcodictyon*, reported to have been originally vermilion. The stolon is not continuous but broken up into patches of varying lengths. In some cases a single strand does not branch at all, whereas another strand may give off many sub-strands, all of which originate at the bases of the polyps.

The polyps are usually in single file and the stolon is then 2 mm. wide, but they are sometimes arranged alternately, giving a zig-zag effect, when the stolon is slightly wider. There are many round, oval, or square flattened patches of stolon, each of which has from two to five polyps and has lost the ribbon-like appearance. These patches possibly represent a stage in the evolution of the ribbon, for the polyps are so arranged as to indicate the beginnings of an "anastomosis." Similar enlargements of the stolon are reported in *S. catenatum* by Herdman (1883), but not by Hickson (1921). Specimens of *S. catenatum* in the British Museum (Natural History) have the polyps arranged in single file, although in a specimen from the Shetlands two polyps were occasionally situated together. This expansion of the stolon seems to supply a transition to the expanded lamellar stolon of the other genera of Stolonifera, e. g., *Clavularia*. There are also isolated polyps dotted on different parts of the sponge which are young forms (see later).

The stolon, flattened from above downwards, forms a thin crust, which is thickest in the middle of its breadth. The surface is exceedingly rough to the touch, owing to the tightly packed spicular elements. The edge of the stolon also is fringed by the protruding needle-like spicules. Between the polyps on the surface of the stolon is a mass of densely-packed rods, needles, and stars, all arranged in a criss-cross manner; lying above these are large irregular masses which are often pink and obviously responsible for the vermilion colour of the colony.

The polyps, which are all retracted, form dome-shaped prominences, and the calyx, consisting of eight lobes, and protecting each retracted polyp, is

the most obvious structure in each prominence. These calyx-lobes are hard cone-like structures, quite distinct from one another, and ending in blunt points round the apparent mouth. The width of each polyp is 1·75–2 mm., and the distance between the bases of two consecutive polyps is usually ·5 mm., although in some cases the bases of the prominences are practically touching and occasionally are ·75 mm. apart. All these distances are much less than in *S. catenatum* described by Herdman (1883), where the distance between the two polyps is at least 1·5 mm. The terminal aperture or "mouth" is really the termination of the non-retractile side-walls of the polyp body and varies in size according to the degree of contraction of the polyp. In one or two cases it was so wide as to disclose the upper part of the polyp body bearing the true mouth and tentacles. The true mouth is ·75 mm. wide, and from the crown surrounding each one are eight tentacles of uniform size, but very short in comparison with Herdman's specimen; possibly they are rather contracted. The average length is ·418 mm., although the longest one measured ·796 mm., whereas those of Herdman's measure 2–2·5 mm. The tentacles are broadest in the middle of their length, usually ·088–·132 mm.; also they are mesenteric in position and are covered with exceedingly minute irregular calcareous spicules, which I discuss later. They taper to rather a blunt point and bear small rounded protuberances, the pinnules, on their lateral edges. The pinnules first appear as very slight elevations, giving the edges towards the base of the tentacles a wavy appearance. Gradually small rounded protuberances evolve which are longest in the wide central part of the tentacle and decrease towards the blunt tip.

Male reproductive organs, not hitherto recorded in the genus, are present in this specimen at different stages of development, but none actually mature. Attached to one mesentery is a small rounded body ·058 mm. long and ·942 mm. broad, consisting of a number of rounded cells covered by a layer of endoderm cells. Other groups of cells representing more advanced stages in the production of spermatozoa are present, the most mature form being ·187 mm. long, consisting of a mass of densely packed cells at the periphery and a coagulum in the centre.

The spiculation of the colony is of outstanding interest and is closely bound up with its habitat, for besides the typical calcareous spicules various kinds of silicious sponge-spicules are found in large numbers in all parts of the colony. Their presence is a remarkable phenomenon, for they form part of the organization and support of the *Sarcodictyon*. Different types of sponge-spicules are found in definite regions of the colony and take the place of the typical calcareous spicules, which are very poorly developed, a striking contrast to previously recorded species of *Sarcodictyon*.

It is a curious fact that the spicules of the sponge to which the *Sarcodictyon* is attached are but little represented, those from other sponge genera preponderating. Spicules from the following genera may be recognized :—

*Stellata*, *Geodia*, *Pachymatisma*, *Donatia*, *Latrunculia*, *Halichondria*, and *Suberites*. The majority, however, are the needle-like oxea typical of *Halichondria*.

The problem as to how these sponge-spicules have become incorporated by the *Sarcodictyon* may be met by alternative suggestions: firstly, that the spicules have been deposited on to the surface of the colony; and, secondly, that the colony has collected the spicules from the dermal membrane of the sponge. The former suggestion is comparable with the behaviour of certain sponges which are capable of utilizing foreign sponge-spicules which may settle on them. It is well known, also, that sponges may incorporate the spicules of other sponges, for frequently one sponge attaches itself to another sponge, and if the upper one dies it is noticed that macerated spongin remains as a covering, whilst the spicules penetrate the living sponge. *Clathria typica* provides an excellent example of these phenomena, for the dermal membranes are full of foreign spicules.

The constant orderly and definite arrangement of the spicules in the *Sarcodictyon* and the absence of sponge-spicules on the upper surface of young forms (as described later) suggest the incorporation of the spicules from the dermal membrane of the sponge. Their transportation may be compared with the transference of spicules known to occur in sponges.

The distribution of the spicules is as follows:—

**A. Surface-layer of Stolon.**—This area presents an exceedingly rough surface, which is quite different from the granulated texture of *S. catenatum* described by Herdman (1883). It is due to the numerous and various sponge-spicules and irregular pink calcareous masses densely packed together forming a hard inflexible wall. The calcareous bodies, true Alcyonarian spicules, which are not closely packed, as in *S. catenatum*, are responsible for the vermilion colour of the living colony. They vary both in size and shape, the average diameter being .044 mm.; but some are .073 mm., and a few measure .119 mm.

The following sponge-spicules are present:—

(1) Oxea, .066–.11 mm. in length, typical of *Halichondria*, are in the majority.

(2) Spherasters, few in number.

(3) Microrhabdi, a form peculiar to *Geodia* and *Pachymatisma*.

(4) Large and small triradiates.

(5) A few anatriænes, orthotriænes, and large oxeotes.

(6) Many forms of styli, the majority being tylostyli. These monaxon forms, .013–.022 mm. wide, are very obvious in this upper region of the stolon, and are arranged in a "criss-cross" manner with the smaller spicules packed in between.

(7) A few dendritic forms.

(8) Acanthostyli, the true *Clathria* spicules, which are few in number.

B. *Middle Part of the Stolon*.—This part consists of the mesoglœa in which are a large number of lacunæ, giving a trellis-work effect which is found chiefly towards the outer edges of the stolon. The narrow interlacing bands of mesoglœa separating the lacunæ contain the endodermal tubules (which communicate with the spaces), together with the oxea averaging  $\cdot 07$  mm. in length and a scattering of exceedingly minute irregular calcareous spicules averaging  $\cdot 0088$  mm. in length.

C. *Lower Part of the Stolon*.—The majority of the spicules are the silicious oxea varying in length from  $\cdot 08$ – $\cdot 19$  mm. There are also a number of large oxeotes and a few tylostyli and orthotriænes. There is a sprinkling of the Alcyonarian calcareous spicules in the form of exceedingly minute irregular bodies averaging  $\cdot 0055$  mm. in length—very different from the large variety in the upper part of the stolon.

D. *The Calyx-Lobes of the Polyps*.—The walls of these cone-like protective lobes are formed of oxea,  $\cdot 0165$  mm. in length and  $\cdot 0132$  mm. in width, larger than those in other parts of the colony. They are arranged “en chevron,” leaving the inner part of the lobe-wall free, except for the minute irregular calcareous spicules,  $\cdot 0055$  mm. in length. A very few tylostyli are occasionally found at the base of the lobe.

E. *The Polyp Body-Wall*.—Exceedingly minute irregular calcareous spicules, similar to those in the lower part of the stolon, occur. Towards the base of the polyp they are more numerous and are accompanied by a few oxea placed at right angles to the main axis of the polyp.

F. *The Tentacles*.—Minute calcareous spicules are scattered on both surfaces of the tentacles. They are oval, square, or triangular bodies, some being bilobed, and presenting a figure-of-eight appearance. They vary in length from  $\cdot 0088$ – $\cdot 0132$  mm.

In the younger colonies the spicular elements are somewhat different from those of the older ribbon-like colonies. Young forms of one or two polyps present a granulated appearance as if coated with sugar, and so approach *S. catenatum* described by Herdman (1883). A young form of only one polyp has a smooth upper surface, no silicious sponge-spicules being present. The lower part, apposed to the sponge, has a few oxea. The colony of two polyps has a few large oxeotes on the upper surface and the edges of the short stolon appear fringed due to the projection of the oxea from the margin. This young stage, however, is very different from the older ribbon.

Comparison between this specimen, the specimen described by Herdman (1883), specimens of *S. catenatum* from British seas, those in the British Museum (Natural History), and Hickson’s specimen from Adelaide shows the following differences :—

(1) The stolon of my specimen is 2 mm. wide, where the polyps are in single file and often broader. In Herdman’s *S. catenatum* the width is

1.5 mm. and may be less. Hickson's *S. catenatum* has the strands still narrower, 1 mm. wide, and Museum specimens were also 1 mm. wide.

(2) Rough surface of the stolon. Whereas the surface of *S. catenatum* is smoother and presents a more granulated appearance.

(3) Spicules.—The true Alcyonarian calcareous spicules are poorly developed and do not form a dense layer as in *S. catenatum*, where they are well developed. Silicious sponge-spicules help in the support.

(4) The distance between the polyps is less than in *S. catenatum*. In my specimen their bases are usually .5 mm. apart and they are frequently touching; in *S. catenatum* they are 1.5–2 mm. apart.

(5) The tentacles are shorter, being .4–.79 mm. long, for even after allowing for contraction there is an appreciable difference from those of *S. catenatum*, where they are 2–2.5 mm. long.

The other known species, *S. agglomerata*, described briefly by Forbes (1853), is in the British Museum (Natural History), and comparison shows agreement in the following external characters:—

- (1) Rough surface.
- (2) Broad connecting ribbon.
- (3) Arrangement of polyps in single file, though often in clusters of two or three.

The two specimens differ in:—

- (1) Colour.—*S. agglomerata* is ochraceous-yellow, whereas my specimen was vermilion. Colour, however, is not a safe specific character.
- (2) Spicules.—The rough surface in *S. agglomerata* is due to the true Alcyonarian calcareous spicules, which are very well developed. In my specimen the calcareous spicules are poorly developed, and the large monaxon sponge-spicules are mainly responsible for the rough surface.

#### Genus XENIA Savigny.

*Distribution.*—This widespread genus, consisting of few species, occurs for the first time in West Australian waters. Essentially a warm-water genus, the presence of the four specimens in the collection is significant. These specimens were characteristically attached to coralline masses and found in littoral waters. The absence of the subgenus *Heteroxenia*, confined to warm seas, with the exception of *H. capensis*, is to be expected. The siphon-like tubes in the specimens, suggesting dimorphic *Heteroxenia*, are young forms of *Xenia*. It is impossible to include *Heteroxenia* with *Xenia*, as suggested by Kükenthal (1902), until it is shown that siphonozooids are immature autozooids, which would ultimately develop.

*Phylogeny.*—May (1900) considers the family Xeniidae to be derived from *Clavularia*, the main difference being in the evolution of the cœnenchym. A better-developed cœnenchymal mass at the base of the polyps, due to their union, gives a better support and a better nutrition than a creeping

membrane. The specimens of *Xenia* in this collection show an intermediate stage in this evolution, for the stolon in all the specimens is membranous and there is only a slight union at the base of the polyps; these are not young forms, as shown by the presence of genital products. Tentacles vary in species of *Xenia*, some having wart-like pinnules arranged in a few rows, others having longer pinnules in many rows. Specimens in the collection show this variation, and one is so specialised that pinnules are on both sides of the tentacles. Hence the orders Stolonifera and Alcyonacea are linked together, *Clarularia mollis* with its thin membranous stolon providing the link. The specimens of *Xenia* in this collection also show how feasible is the suggested connection between *Anthelia* and *Xenia*.

*Classification.*—The genus is in a state of flux and our knowledge of diagnostic characters is still uncertain. New and slightly varied characters appear in every work on *Xenia*, and probably in the future there will be merging of several species into one which will have more elastic diagnostic characters. The origin and character of the spicules in *Xenia* separate the genus from all other Alcyonaria, but their specific value is questioned by some. Early writers maintained that it was negligible, but Kükenthal (1911) points out that variability in form of the disc-like spicules can be used as a reliable specific character. Little attention has been paid to the distribution of spicules in a colony of *Xenia*. This, together with their form and nature, will probably be of specific importance in the diagnosing of species in future.

All writers agree that the size of the polyp can be utilised systematically only in very rare cases, because of variability in a single colony; this may be either modificational and due to contractility of polyps or to differences in their age.

Great systematic significance has been attached to the tentacles and pinnules. Schenk (1896) regarded the structure, size, and distribution of the pinnules in the tentacles as constant characters, and he established three subgenera, but, later, May (1900) ignored the size and number of pinnules per row as specific characters. Ashworth (1900) revised Schenk's classification table, but Thomson (1905, 1908) maintains that the size and arrangement of pinnules are often misleading owing to contraction and to the presence of immature forms. Kükenthal (1902, 1912) attaches importance to the structure of the tentacles and arrangement of the pinnules in the determination of species, but in 1911 states that these may lead to erroneous conclusions owing to contraction. He suggests determining the number of pinnules in the transverse row at the base of the tentacles. It is difficult to consider even this as a safe character, for the pinnules at the base of the tentacles frequently do not originate at the same level. Undue importance should not be attached to the bare strip on the middle of the inner surface of the tentacles, since it is apt to be obscured or exaggerated according to the degree of contraction.

All writers are agreed that the form of the stalk is not a sufficiently constant character for the establishment of new species, although the stalk should be taken into consideration with other more constant characters.

*XENIA BLUMI* Schenk var. *PELSARTI*, nov. (Pl. 33. figs. 2-7.)

*Locality*.—Pelsart Island, shore collection. One specimen.

The colony consists of membranous patches creeping irregularly over the surface of coral; the thickness of the patches at the centre is approximately 1.5 mm., but towards the margins they are extremely thin, often being merely the thickness of paper.

The polyps, arising from the upper surface of the creeping stolon, have very little support, for if the specimen is removed from spirit the polyps collapse as a tangled heap on the membrane. In common with many writers I use "polyp" to indicate the free portion of the polyp. The distance between the polyps varies considerably, for in a few cases their body-walls are attached for a very short distance at the base, whereas in other cases they may be 1 mm. apart. The wall of each polyp is very thin, and it is possible to see the stomodæum and mesenteries through it. The stomodæum is fairly long (2.6 mm.) and the mesenteries are typical. The polyps are extremely slender and vary considerably in length, for the body is from 8-10 mm. and the tentacles average 5 mm.; the average width of the polyp body is 0.75 mm. and that of the tentacles 0.214 mm. The slender tentacles are usually in a straight line with the polyp body and have pinnules confined to the upper surface; these are arranged in three rows on either side of the middle line and in mature forms are of two kinds. Towards the proximal end are wart-like protuberances similar to the pinnules of young forms, while those towards the distal end are tongue-shaped, gradually decreasing in size towards the tip of the tentacle. The basal part of each tentacle is free from pinnules for a distance varying between .2 and .42 mm., but the first definitely rounded protuberance is usually .882 mm. from the base; up to this distance the two lateral edges are merely wavy in outline. There are from eighteen to twenty-five pinnules in each row, the outermost one on each side developing before the other rows, as is evident by the progressively lower level of origin of the pinnules in passing from the outer to the inner row. Thus, whilst the pinnules of the outermost lateral row on either side have become longer and more tongue-shaped, and average .25 mm. in length, the pinnules of each middle row are not so long, being .219 mm., and those of each inner row present a rounded appearance with a length of .126 mm. In the distal half of the tentacle, however, the pinnules are all similar and tongue-shaped, measuring  $.126 \times .09$  mm. The rows are much less definite in this region and the two innermost rows arise practically from the middle line. Towards the extreme tip, where the pinnules are smaller, they are irregularly scattered on the whole inner surface of the tentacle. Towards this proximal region it



is difficult to recognise the three rows, for the pinnules arise more or less alternately.

Young forms at varying stages occur on practically every patch between polyps with fully-developed tentacles. The youngest forms, appearing as small pimple-like buds with a central hole, are situated towards the edge of the colony, whilst older forms with the beginnings of tentacles are further removed from the edge. I thought at first that the small forms indicated dimorphism, but on further examination I found intermediate transitional stages between the siphon-like forms with no tentacles and the adult forms with eight pinnate tentacles.

*Stages observed in the Development of the Tentacle.*

(1) The youngest polyp appears as a cushion-like prominence with a central hole, at the margin of which there are eight indentations. The largest measures 0.2 mm. long.

(2) The polyps averaging .524 mm. have unequal tentacles appearing as small tubular structures bending in towards one another like curved fingers, the longest of which (.154 mm.) curves round, meeting at the tip a shorter curved protuberance from the opposite side.

(3) Another young form has two tentacles, .5 mm. long and closely apposed, but there is no sign of pinnules.

(4) One young form has six tubular tentacles of varying length flattening out at the distal end. The longest, .693 mm., has the beginnings of pinnules which appear .441 mm. from the base as three minute elevations on either side.

(5) Another form with closely apposed tentacles up to 1 mm. long has faint suggestions of pinnules occurring .2 mm. from the base, the largest being .033 mm. long.

(6) In a slightly older form, having tentacles 2.14 mm. long, pinnules arise .31 mm. from the base at the edges, and are .08-.11 mm. long. Higher up the tentacle and situated more ventrally is the beginning of the second row of pinnules on either side.

(7) Gradually the tentacle lengthens and the third row of pinnules appears on either side; those of the outer row towards the distal end become gradually more tongue-shaped, while those of the inner row are still rounded protuberances.

(8) In developed forms the lower pinnules are wart-like and the upper ones are tongue-shaped; there are three rows on either side, each with eighteen to twenty-five pinnules. The members of a row are not so numerous in young forms and are not closely situated; thus the origin of the protuberances can be seen and the mid-ventral line of the tentacle is left quite free. As the second and third rows evolve the mid-ventral free space is confined to

the lower part of the tentacle as the upper part becomes covered with the more closely apposed longer pinnules.

The spicules in the colony, which are confined to the ectoderm, are of horny consistency with an organic basis impregnated with calcareous material. All are flattened, oval, bilobed structures with average measurements of .016–.019 mm. long and 0.11 mm. wide, the front view appearing almost circular. Although fairly abundantly distributed towards the base of the polyp body-wall, they are not numerous enough to touch one another. In the upper region there are practically none. The longitudinal axis is usually parallel with the axis of the polyp and the edge or flat face is presented indifferently to the surface. Spicules are more numerous at the base than towards the distal end in the tentacles. A very few spicules are scattered at the base and margin of each pinnule, more being present in the rounded forms than in the tongue-shaped variety. The contractility of the polyps, evident by the transverse grooves seen in the stomodæal region, is associated with the scarcity of spicules, as is the difference in length of adult tentacles (those averaging 13 mm.). The tongue-shaped pinnules vary in length owing to contraction, thus debarring their specific use. Spicules are evident in the young forms. In stage (2) there are a few spicules .012 mm. long in the polyp body-wall but none in the smaller tentacles. Spicules are seen in polyps at stages (4) and (5); they are .0176 mm. long in the body-wall, .008–.013 mm. long at the base of the tentacles, and .006–.008 mm. long at the tip.

In the development of the sperm-sac all stages are evident from the germ cells, with large nuclei and reticulate protoplasm in the mesogloea of the mesenteries, to the well-developed sperm-sacs almost filling up the cavity of the cœlenteron. These sacs are somewhat hexagonal in outline owing to pressure, and the largest observed is .242 mm. in diameter and is packed with cells. No small central cavity as described in *N. hicksoni* by Ashworth (1899) is observed.

This specimen resembles *Xenia blumi* Schenk previously recorded from the hot waters of Ternate (Moluccas).

It agrees in :—

(1) Pinnules situated only on the ventral surface in three rows at each side leaving the axis free; in their number and occurrence in two varieties.

(2) Tentacles—their shape and length.

(3) Spicules—of the usual shape and size, and agreeing with May's diagnosis (1900) in that they are not numerous. Other authors do not mention the distribution.

It differs in :—

(1) No supporting trunk but only a membranous stolon. Kükenthal's description is nearest to this in which he says that the base of the colony is a thick fleshy individual stem from the upper surface of which arise the polyps.

(2) Polyps have a greater average length and are narrower than those in Ashworth's diagnostic table. Too much importance must not be attached to this character, for the variations may be due to contraction.

*XENIA TERNATANA* Schenk var. *LITTORALIS*, nov.

*Locality*.—Pelsart Island, shore collection. One specimen.

The colony is a white flattened membranous mass creeping over coral. Polyps of one variety arise from the upper surface and are less thickly distributed towards the margin, where they may be 1 mm. apart, than in the central area; the extreme edge is devoid of polyps. The bases of the polyps in the centre of the membrane are usually in contact, and often the ectoderm of two adjacent polyps is fused for about 1 mm. Even some young forms have their bases joined for a distance of .75 mm. In some parts there is a suggestion of a stalk, due to the joining together of as many as five polyps in the basal region. These are often well-developed polyps with reproductive elements. Polyps in all stages are present as in the previous species. Their walls are so thin that the stomodæum and mesenteries are visible; only the two dorsal mesenteries have well-developed filaments which run in a sinuous course to the base of the polyp. The length of the polyp body is from 5–8 mm. and the width averages .75 mm. The tentacles are 4 mm. long and 5 mm. wide. The stomodæum is proportionately short, being .819–1.4 mm. long. The tentacles have two rows of pinnules on either side of the middle line on the ventral surface, numbering from 18–20 per row, arising alternately and having many zoochlorellæ. The pinnules towards the proximal region of the tentacles are more rounded than those towards the distal end, which are longer, almost pointed structures, with an average length of .144 mm. and .063 mm. wide at the base. A very few are more distended, appearing thinner and longer, .17 × .056 mm. There is no doubt that contraction is responsible for the slight variability in size of these pinnules, all of which decrease towards the tip. The extreme base of the tentacles is devoid of pinnules for a distance of .35 mm.

The polyps, when out of water, collapse and appear as a tangled heap lying on the basal membrane, in consequence, no doubt, of the scarcity of spicules. Spicules are absent from the lower region of the polyp body-wall, but towards the stomodæal region a few are scattered in the wall. In the region of the origin of the tentacles there are more, and a few are found in the base of the tentacles, but no two touch one another. All are confined to the ectoderm and are typical of the genus. They are flattened, bi-lobed, oval forms which present different surfaces to the exterior so that some appear almost circular. They measure .0198–.022 mm. in length and are .012 mm. wide. Reproductive elements in different stages of development are present, the largest of which are obviously immature sperm-sacs. The growth of each of these sacs from a single genital cell on the mesogloea of

the mesentery can be traced in the different stages, *e.g.*, 8-celled stage, in this specimen.

The specimen approaches most closely *Xenia ternatana* described by Schenk from Ternate (Moluccas) (1896). Kükenthal (1902) and Ashworth (1900) also describe this form, and Thomson and Henderson (1906) establish a new variety "*elongata*" for a specimen in the Zanzibar collection.

This variety agrees with *X. ternatana* in the following :—

(1) Pinnules arranged in two regular rows on either side of the ventral surface, leaving the mid-line free. Pinnules rounded below and long in the distal region.

(2) Tentacles slender and long.

(3) The measurements of the polyps.

The following differences characterize the new variety :—

(1) Number of pinnules per row, which is less than in both the type-species and the variety *elongata*.

(2) No supporting trunk but a membranous stolon. The latter is a characteristic of *elongata*, but the polyps are shorter in this specimen.

(3) Sparse distribution of the spicules, whereas Kükenthal, the only previous writer referring to their distribution, speaks of them as absent only from the pinnules.

*XENIA DEPRESSA* Kükth. var. *KÜKENTHALI*, nov. (Pl. 30. fig. 3.)

*Locality*.—Pelsart Isle, shore collection. Two specimens.

These two membranous greyish-white colonies occur as creeping masses on pieces of coral. The stolon, of leaf-like thickness at the margin and only 1 mm. in the middle, has the polyps arising from the exposed surface quite independently but close together. In many cases the walls of two adjacent polyps are fused for a very short distance. Young forms situated between the more mature polyps occur towards the edge of the stolon, which is free from polyps for a margin of 2 mm. The evolution of tentacle and pinnule is comparable with that in *Xenia blumi* var. *pelsarti* previously described. The polyps are extremely long, especially in the larger specimen, for the polyp body-wall is 8–15 mm. long and .8–1.2 mm. wide, with tentacles 6×.5 mm.; the walls are transparent. Some polyps are shorter and have thicker walls, contraction being evident in the transverse rings in the wall of the stomodæal region. Variation in quantitative characters may also be due to local environment. The stomodæum measures 1.5 mm. in length, although in contracted polyps the average length of the stomodæum is only 1 mm.

The pinnules are all of the long tapering variety and of varying length due to contraction. The average measurements are .25–.37 mm. in length and .037 mm. in breadth in the middle; towards the base and tip of each tentacle they are shorter and cone-like. Two rows, each consisting of

18-20 pinnules, are situated on both surfaces closely apposed. Towards the base of the tentacle, for a distance of  $\cdot 2\text{--}\cdot 3$  mm., there are no pinnules.

Correlated with the collapsible nature of the polyps there is a scarcity of spicules, these being sparsely distributed and confined to the terminal pinnules. Their number probably varies in inverse proportion to the numbers of zoochlorellæ, which are in profusion. The spicules are elliptical bilobed structures  $\cdot 017\text{--}\cdot 022$  mm. long and  $\cdot 015$  mm. wide and are variously orientated.

Reproductive elements are not well developed in either specimen. Both have immature sperm-sacs attached to the mesenteries, the largest sac,  $\cdot 094$  mm. in diameter, being filled with cells which ultimately give rise to spermatozoa.

These two specimens approach *Xenia depressa* Kükenthal, 1912, the locality of which is unknown and which resembles *X. bauiana* May.

Resemblances to *X. depressa* are as follows :—

- (a) Membranous stolon with closely apposed polyps.
- (b) Pinnules on both surfaces of tentacles.
- (c) Form of spicules.

Differences are :—

- (a) Scanty distribution of spicules.
- (b) Fewer pinnules in a row.
- (c) Narrower polyps with transparent walls in the expanded forms.

#### Genus *ALCYONIUM* Linn.

*Distribution*.—This is a very wide-spread genus, since species occur on the coasts of all seas, both in temperate and tropical zones, thus differing from the majority of Alcyonaria. From Australian waters only a single specimen of *A. pachyclados* has been recorded, Kükenthal (1910).

*Classification*.—Klunzinger (1877) gave a most elaborate scheme of classification which has been used to some extent by all later authors. May (1900) and Schenk (1896) revised it, and the more recent writers, including Hickson (1895, 1900, 1903, 1905), Kükenthal (1910), and Thomson (1908, 1911, 1921), based much on the scheme, which, however, they criticised. No new scheme of classification has entirely usurped that proposed by Klunzinger, although many new species have been created and more attention has been paid to the internal organization of the colony. The systematic arrangement of the genus is unsatisfactory, and a necessary revision will result in the grouping together of many known species into one larger species having more elastic diagnostic characters. A more satisfactory systematic arrangement would result from greater stress being laid on the age of the spicules, their distribution and the avoidance of confusion between the stages of growth and the different forms of

spicules. There is more uniformity in species of *Alcyonium* than in other genera. The slight differences between many species were termed individual fluctuations by Thomson and McQueen (1908). Although they suggested including *A. pachyclados* with *A. sphærophorum*, the large size of the dumb-bell spicules in the former suggests that it should be regarded as a distinct species. The genus, distinct from other genera of the Alcyoniidæ in having only one kind of zooid, at one time was divided into two subgenera. Forms from cooler waters were classed as *Alcyonium*, and those from warm waters as *Lobularia*. It is now agreed that there is no evidence for the establishment of *Lobularia* as distinct from *Alcyonium* and only the latter is retained. Little stress is laid on the anatomy of *Alcyonium* colonies and, apart from Hickson's work (1895) on *A. digitatum*, little is known. Possibly the variation in size and arrangement of the pinnules may in future be of systematic value. Thomson and Henderson (1906) give data regarding the tentacles of *A. pachyclados*, and S. Thomson (1921) refers to the colour of the tentacles and spiculation, but these authors do not attach any specific importance to these facts.

All the specimens, except one which is *A. digitatum* and hence of interest in these waters, I consider to be members of *Alcyonium sphærophorum*, a species with many varieties, including many of Klunzinger's species. The differences between the varieties depend on the size and proximity of the lobes to one another and the size and distribution of the two kinds of spicules. Undue importance must not be attached to size until the age of a colony is determined and genital products have been examined.

ALCYONIUM SPHÆROPHORUM Klunzinger var. AUSTRALIENSIS, nov. (Pl. 31. fig. 1; Pl. 34. figs. 1, 2.)

*Locality*.—Wooded Island. One specimen.

This specimen, 8 mm. high, consists of an extremely short, wide stalk 4×10 mm., attached to coral, and a much lobed capitulum. The stalk is visible only one side owing to the overgrowth of the brain-like capitulum. The latter, 14 mm. wide, has numerous bullet-shaped lobes 5×5 mm. in such close proximity that the sides and basal parts are flattened and the upper parts rounded. The whole colony is extremely hard, all exposed surfaces having a white sugar-like coating consisting of small figure-of-eight spicules. The true colour of the colony is pale brown. The polyps, of one kind only, are in different stages of retraction, the majority being completely retracted within the coenenchymal mass, thus leaving the white coating very evident. The crown of each polyp bears eight similar pinnate tentacles with pinnules on each side. The latter are short bent fingers turning inwards, the proximal ones, .088 mm. long and .041 mm. wide at the base, being the longest. They originate .088 mm. from the base of the tentacle and are arranged in two ventro-lateral rows of five pinnules.

The two varieties of spicules are elliptical bilobed forms and dumb-bells with spinose heads. The distribution is as follows :—

(1) The body-wall of the polyp contains elliptical forms  $\cdot 035$ – $\cdot 044$  mm. long. They are usually touching or overlapping in the upper part but are scanty in the lower part.

(2) The crown bearing the tentacles is packed with elliptical forms, a few of which extend up the mid-line of the aboral surface of each tentacle.

(3) The tentacles have a small variety of elliptical forms  $\cdot 0264$  mm. long, scantily distributed in the aboral region.

(4) The pinnules are devoid of spicules.

(5) The surface of the lobed capitulum has elliptical spicules which are densely massed together to form the white coating. The majority have only a slight waist and are  $\cdot 048 \times \cdot 0176$  mm. ; others, somewhat larger,  $\cdot 052 \times \cdot 022$  mm., have a more definite waist and a few have the ends rather square. A few forms are small rounded spicules  $\cdot 028$  mm. in diameter, and some are quadrilobular  $\cdot 035 \times \cdot 026$  mm. Although the type-spicule has the form of a figure 8, the presence of the young, minute, rounded forms which give rise to them bears out the suggestion that spicules originate in the ectodermal layer. Further development of the spicules gives rise to the larger dumb-bells of the interior, and a suggestion of this is shown by the larger elliptical forms with their square ends and the quadrilobular forms in this surface-layer.

(6) The upper part of the lobed capitulum has mostly elliptical spicules  $\cdot 039$ – $\cdot 051$  mm., which are packed closely together. Some larger ones, about  $\cdot 057$  mm. long, present a more irregular edge and are a transition-stage to the dumb-bells, a variety which is rare. The latter are  $\cdot 088$  mm. long and  $\cdot 026$ – $\cdot 035$  mm. wide and have a slight neck and two heads covered by short rounded spines.

(7) The lower part of the lobe is not densely packed with spicules ; some of them are elliptical forms, but the majority are transitional irregular forms and dumb-bells with heads covered with pointed spines.

(8) The spicules of the stalk and cortex are similar in that all are of the dumb-bell variety with a smooth, short, broad neck and heads covered with short blunt spines. They measure  $\cdot 088 \times \cdot 035$  mm. and are thickly distributed.

I found no trace of reproductive elements and possibly the colony may be a young form, although the distribution of the spicules in the tentacles suggests maturity.

*ALCYONIUM SPHÆROPHORUM* Klunzinger var. *SAXIGENA*, nov. (Pl. 30. fig. 4 ; Pl. 31. fig. 2 ; Pl. 34. fig. 3.)

*Locality*.—Reef, Pelsart Group. One specimen.

This specimen is a fleshy-lobed dirty white mass attached to a piece of white coral. The broad, smooth, sterile stalk, 45 mm. wide and 20 mm. high, has at the distal end the convex, lobed, somewhat brain-like capitulum, which is a little wider than the stalk and bears the monomorphic polyps. The capitulum divides into a few extremely short thick branches upon which the polyp-bearing lobes are thickly crowded, so as to overhang the stalk on one side. The lobes,  $10 \times 7$  mm., have the polyps in close proximity, especially on the exposed rounded tip, where the average distance is .088 mm. Polyps situated between two lobes are often 1 mm. apart and all are in different stages of retraction. The crown of each polyp supports eight pinnate tentacles .462 mm. long. The pinnules originate .088 mm. from the base of the tentacle and are situated in a lateral row each consisting of five pinnules. The most expanded pinnule measures .132 mm. in length and .062 mm. in breadth at the base, but towards the proximal end of the tentacle the pinnules are more rounded.

There are two varieties of spicules, viz., typical bilobed forms and spinose dumb-bells. Their distribution is as follows:—Both body-wall and the crown bearing the tentacles are quite free. At the base of some of the tentacles there are from two to five minute oval disc-like spicules, modified elliptical forms, .0352 mm. long. The surface-layer of the lobed capitulum is densely packed with elliptical spicules of specific form and size. Some forms are transitional to the dumb-bells; they are bilobed ovals, .055 mm. long with irregular ends, dumb-bells .077–.083 mm. long with a narrow neck .0176 mm. wide and a cluster of rounded protuberances at each head, and also quadrilobular forms .046 mm. long. Inside the capitulum are many spicules showing the evolution from the figure-of-eight variety to the dumb-bells with well-developed spinose heads. The cortex of the stalk has very few spicules, there being an average distance of .044 mm. between the two, and all are of the dumb-bell variety with short broad spines at each head, leaving a short, smooth, thick neck. They measure .07–.088 mm. in length and .022–.035 mm. in width. A few elliptical forms are also present. Inside the stalk at both proximal and distal ends there are only the spinose dumb-bell spicules.

Sperm-sacs at different stages of maturity are attached in clusters to the mesenteries of the polyps. The smallest observed was .033 mm. in diameter at the eight-celled stage; the largest was .077 mm. wide, packed with a mass of cells which would ultimately develop into spermatozoa. No sacs were mature.

**ALCYONIUM SPHÆROPHORUM** Klunzinger var. **LITTORALIS**, nov. (Pl. 31. fig. 3; Pl. 34. fig. 4.)

*Locality*.—Wooded Island, shore collection. One specimen.



This greyish-white specimen is broader than high (30 mm. wide and 15 mm. high) and consists of a short, broad, sterile stalk (4 mm. long, 10 mm. wide) supporting a lobed polyp-bearing capitulum. The soft leathery stalk, attached to coral, with the capitulum overhanging at one side, has a smooth surface showing transverse grooves, possibly a sign of slight contraction. The capitulum branches slightly, each branch having 3-7 lobes of varying size, usually measuring 5 × 5 mm. A number of smaller lobes arise immediately from the capitulum between the short branches. The monomorphic polyps in different stages of retraction are confined to the lobed capitulum. They are not so closely situated (being 1 mm. apart) at the base of and between the lobes as they are at the rounded ends of the lobes, where they almost touch. I could not determine the true size of the polyps as none was fully expanded. The crown of the polyp bears eight pinnate tentacles, which are free from pinnules at the base for a distance of .11 mm. There are two rows of six pinnules each at either side of the tentacle, which terminates in a pinnule. The pinnules are rounded cone-like structures packed with zoochlorellæ; their average measurements are .088 mm. long and .066 mm. wide at the base.

Two kinds of spicules, bilobed elliptical forms and short broad dumb-bells, are present. They are distributed as follows:—

(1) In the polyp body-wall are bilobed ovals .04–.05 mm. long and .0154 mm. wide. Some have lost their regular shape and have minute rounded protuberances at either end; some appear as dumb-bells .066 mm. long with a cluster of rounded spines at the heads. They are more closely packed at the upper end, and the majority have their axes parallel with the axis of the body-wall.

(2) The crown bearing the tentacles is fairly well packed with spicules at right angles to the tentacle axis. They are elliptical, the largest .05 in length. Some are slightly irregular ovals.

(3) The surface of the capitulum is not thickly covered with spicules. A few are elliptical, but the majority are dumb-bells with blunt spines from two to four in number at each head. These are .056–.088 mm. long and .022–.04 mm. wide at the smooth neck. A few forms are spinose and quadriradiate (.056 × .026).

(4) The inside of the capitulum has very few spicules but more variety of form is shown. The majority are dumb-bells with a few elliptical and quadrilobular forms.

(5) The stalk has many spicules in both cortex and deeper layers. The majority are broad dumb-bells .079–.096 mm. × .033 mm. At each head are broad spines.

No reproductive elements are evident in this colony.

Table of Comparison between Varieties of *Alcyonium sphærophorum*.

	<i>A. sphærophorum</i> Klunzinger.	<i>A. sphærophorum</i> var. <i>australiensis</i> .	<i>A. sphærophorum</i> var. <i>surrigena</i> .	<i>A. sphærophorum</i> var. <i>littoralis</i> .
Lobes of Capitulum.	Bullet-like lobes flatly spherical, close together, broader than high.	Rounded bullet-like lobes, laterally compressed towards the base, closely situated.	Rounded finger-like structures, longer than broad, close together.	Rounded bullet-like, not tightly compressed.
Surfaces ....	Granular, white.	Very granular, appears as a white coating.	Leathery, fleshy consistency.	Soft, smooth.
Polyp Spicules	....	Elliptical bilobed, .035-.044 mm. long, packed in upper body-wall. Scanty in lower part.	Elliptical bilobed ovals, .035 mm. long. None in body-wall.	Bilobed ovals, .04-.05 mm. long, dumb-bells with long necks and rounded protuberances at heads. Upper body-wall has many spicules. Lower body-wall has few.
Crown .....	....	Packed with oval spicules.	No spicules.	Packed with spicules.
Tentacles ....	....	Quite a few spicules at the base which extend up the aboral surface.	A few spicules at the base (2-5).	Many spicules at the base, forming a continuous band. A few on the aboral surface.
Pinnules ....	....	Arranged in two lateral rows, 5 per row, bent fingers .088 mm. long.	One lateral row either side, 5 per row. Pinnules .125 mm. long.	Two lateral rows, 6 per row. Rounded cone-like, .088 mm. long.

*ALCYONIUM DIGITATUM* Linn. (Pl. 31. fig. 4.)

*Locality*.—Pelsart Island. One specimen.

This specimen is a large white-lobed mass 50 mm. long and 60 mm. broad, consisting of an extremely wide, short, sterile part 10 mm. long and an upper capitulum consisting of large rounded lobes. The latter bear the monomorphic polyps, most of which are retracted, but the few extended forms are white to transparency, with tentacles each bearing a lateral row of narrow, slender, pointed pinnules, .1 mm. long and .018 mm. broad. The surface of the capitulum is densely packed with spicules, the majority of which are dumb-bells with numerous irregular projections at each end resembling those recorded by Hickson (1895). The surface-layer of the stalk and inside of capitulum and stalk are also fairly closely packed with spicules which are of great variety. There are dumb-bells and also branched

spicules of larger size, together with more irregular forms which have branches radiating from a centre.

Previously found in North European coastal regions.

### Genus SARCOPHYTUM Lesson.

This genus is chiefly confined to the warmer waters of the Indo-Pacific Ocean, and is well represented in collections from these waters. It is found in the littoral region attached to coralline masses, and it is thus of interest to find the genus represented in this collection.

Historically, the names of Marenzeller, Pratt, and Kükenthal are associated with the genus *Sarcophytum*. Pratt (1903) drew comparisons between it and the related genera *Lobophytum* and *Sclerophytum*. Kükenthal (1910) discussed and revised the classification of the genus and compared it with the genus *Anthomastus*. Before Kükenthal's revision the specific characters of the genus were based entirely on external structure. Marenzeller (1886) used the shape and size of the spicules as specific characters, but Kükenthal does not attach importance to size, although in some instances he uses the spicules as generic and specific characters. I consider that if mature colonies are examined the average size of the spicules is as trustworthy as any other quantitative character. Thus some importance should be attached to the size and spininess of the spicules with due regard to slight variations. Kükenthal (1910) suggests that the size of the autozooids is to some extent a specific character, but I would suggest that this depends upon their age and also on the preservation. Only living forms can give correct results. The structure of the polyps, especially the tentacles and the number of rows, size, and number per row of pinnules, is a reliable character. Kükenthal attaches much importance to the distance between adjacent autozooids, which he maintains to be fairly constant. Since those of the rim are closer than those of the middle, owing to growth taking place at the rim, the distance between the autozooids, when used as a specific character, should be measured in the middle of the capitulum.

Kükenthal (1910) reduces the number of species to five, which have more elastic diagnostic characters than formerly; also the number of siphonozooids between adjacent autozooids towards the centre of the capitulum is taken as a reliable specific character.

**SARCOPHYTUM TROCHELIOPHORUM** Marenzeller var. **AUSTRALIENSIS**, nov. (Pl. 31. fig. 5.)

*Locality*.—Wooded Island, dredged from lagoon. One specimen.

The pale green colony is a complete mushroom attached to a mass of coral. The sterile stalk, 30 × 25 mm., appears smooth, but is rough to touch. It is granulated at the base, but higher up it is smoother with a series of longitudinal furrows; near the capitulum there are numerous transverse

grooves, giving the stalk a very wrinkled appearance. The stalk broadens out at the distal end into a broad, almost flattened capitulum 60 mm. wide. This has a marked central depression and at the edge appears wavy, being thrown into a series of folds with seven lappets curving over and covering the distal part of the stalk.

The colony is dimorphic, the autozooids and siphonozooids being confined to the upper surface of the capitulum. This has siphonozooids only in the central concavity, covering a breadth of 12 mm. Bordering on this is an area with relatively few autozooids, 5 mm. apart, with ten to twelve siphonozooids between them. Towards the outer edge of the capitulum adjacent autozooids are 1-2 mm. apart with two to three siphonozooids between. At the extreme edge of the lappets autozooids are often in closer proximity. The siphonozooids are comparatively large, .132 mm. broad, with a small key-hole aperture .088 mm. long; they are closely packed together, being .06 mm. apart. The autozooids, which are nearly all partially or completely retracted, have the tentacles as bluntly finger-shaped structures .504 mm. long. The latter have a single row of six pinnules on either side which are rounded and stumpy, .088 x .044 mm., containing many zoochlorellæ.

The form and distribution of the spicules are as follows:—

(1) The upper part of the wall of each autozoid, often the crown, is closely packed with spicules. These are all slightly curved rod-like forms, .305-.353 mm. long, with a uniform width of .022 mm., having very faint spines. In the lower part of the crown they are perpendicular to the axis of the tentacle, but towards the base of the tentacle they are parallel with the axis. Some slightly smaller rod-like forms are found on the aboral surface of the tentacle giving support. On the oral face are a few minute ovoid bodies .0176 mm. long. The pinnules are devoid of spicules.

(2) The surface of the capitulum between the zooids is packed with three varieties:

(a) Some rod-like forms .24-.35 mm. long with rounded spines.

(b) Many clubs up to .22 mm. long with rounded spines predominating at the wide end.

(c) Many small irregular forms with rounded spines, which give rise to small rods .099 mm. long.

(3) Inside the capitulum are rod-like forms .44-.576 mm. long. Some have small blunt spines at intervals of .022 mm., but some present merely a wavy edge; a number are slightly branched.

(4) The lower granulated outer surface of the stalk has many large spindles the axes of which are parallel with the axis of the stalk. There are four varieties:—

(a) Large spindles .484-.528 mm. long and .11 mm. broad in the middle, covered with irregularly-arranged tuberculated warts.

(b) Shorter spindles or rods  $\cdot 286$ – $\cdot 352$  mm. long and  $\cdot 044$  mm. wide with well-developed rounded spines.

(c) A few clubs  $\cdot 165$  mm. long, similar to 2 b.

(d) Irregular forms, similar to those of the capitulum, which give rise to the short rods  $\cdot 11$  mm. long.

(5) Spicules of the upper stalk differ slightly both in form and distribution and include three varieties :—

(a) Irregular forms such as 2 c and 4 d are in the majority. They give rise to spined rods  $\cdot 11$  mm. long, which possibly develop into the longer rods and spindles of the interior of the colony. This seems to indicate that the spicules originate in the ectodermal outer layer and migrate into the inner mesoglaea.

(b) Spindles  $\cdot 284$  mm. long, similar to 4 b.

(c) A few clubs, similar to 2 b and 4 c.

(6) Inside the stalk are four varieties :—

(a) The majority are spindles  $\cdot 418 \times \cdot 044$  mm. with blunt spines.

(b) Large spindles  $\cdot 528 \times \cdot 11$  mm., similar to 4 a.

(c) A very few clubs, similar to 2 b.

(d) A few irregular forms.

I found no trace of genital organs in the colony.

*S. trocheliophorum* has previously been found in the Red Sea, Port Denison, Torres Strait, and Madagascar.

The specimen resembles *S. trocheliophorum* in the following :—

(1) The appearance and form of the capitulum.

(2) The distribution of the zooids.

(3) The spicules, especially the club-shaped variety with well-developed spines, and the rods.

The following differences characterise a new variety :—

(1) Absence of the typical oval spicules with prickly warts in the inside of the stalk. In my specimen the spindles predominate and there are a few clubs.

(2) The rods and clubs are twice as long as in the type-species, also many irregular forms are present in this specimen.

(3) There is more variety in the spicules of the surface of the stalk in my specimen.

(4) The number of siphonozooids between adjacent autozooids towards the centre of the capitulum in my specimen is greater.

*SARCOPHYTUM ACUTANGULUM* (Marenzeller) var. *OCCIDENTALIS*, nov. (Pl. 31. fig. 6 ; Pl. 34. fig. 5.)

*Locality*.—Dredged off Long Island. One specimen.

One large grey mushroom-shaped specimen represents this species. The sterile stalk,  $95 \times 53$  mm., is attached to a piece of coral and is rough and hard, a characteristic of the whole colony. It broadens out in the shape of a

funnel to the capitulum, which bears the polyps on the upper surface. The latter is almost hidden, owing to two opposite sides of the disc having grown so as to expose the sterile under surface of the capitulum, which is a continuation of the stalk. This gives the outline of the capitulum the appearance of an oak-leaf. The edge of the capitulum, the thickness of which is about 5 mm., presents a fairly hard, stiff, thin edge which bends round slightly towards the under surface.

The colony is dimorphic, the majority of polyps being completely retracted. Hence it has been impossible to make a thorough investigation of the polyps. The autozooids are 5-6 mm. apart towards the centre of the capitulum, but at the edge they are much closer, being 2.5 mm. apart. Between the openings of the autozooids lie the numerous minute openings of the siphonozooids, .05 mm. apart, which become more numerous in proportion to the autozooids towards the central part of the capitulum. They give the surface a pitted appearance. The pinnate tentacles, arising from the crown which surrounds the mouth, are comparatively broad rounded structures .408-.5 mm. long, each tentacle bearing a lateral row of seven lancet-shaped pinnules tapering to a blunt point, which, when completely expanded, are .121 mm. long, .033 mm. broad at the origin, and .043 mm. broad in the middle. They are packed with zoochlorellæ.

The form and distribution of the spicules are as follows :—

(1) At the proximal end of the tentacles there are 6-10 rod-like spicules with their axes parallel with the axis of the tentacle. They have a suggestion of a spinose edge and are .12-.15 mm. long and .088 mm. broad.

(2) The crown has similar but slightly larger rods arranged at right angles to the axis of the tentacles.

(3) The pinnules are devoid of spicules.

(4) Body-wall of the autozoid has rod-like forms, few in number, confined to the distal half.

(5) Surface of the capitulum is closely packed with three varieties of spicules:

(a) The majority are clubs, .11-.16 mm. long, with rounded spines and wart-like tubercles which predominate at the wide end.

(b) A few long thin spindles .198-.33 mm. long and .013 mm. broad, with rounded spines giving rise to more irregular protuberances.

(c) Many small irregular forms, .066 mm. long, with broad rounded spines, some of which are almost square. Some are rod-like, .11 mm. long, and have rounded spines.

(6) Inside the capitulum :—

(a) Long spindles .4-.315 mm. long and 0.44 mm. broad which have whorls of rough, irregular, wart-like protuberances.

(b) A few narrow spindles, .28 × .025 mm., having small rounded spines. All the spicules lie more or less parallel to each other.

(c) A few irregular forms of the surface type.

(7) The surface of the stalk (two varieties) :—

(a) Rod-like spindles  $\cdot 35$ – $\cdot 39$  mm. long and  $\cdot 0176$  mm. wide. These are covered with many rounded spines arranged irregularly.

(b) Clubs  $\cdot 176$ – $\cdot 198$  mm. long with many well-developed tuberculate warts and long rounded spines. These forms are slightly larger than 5a.

(8) Inside the stalk :—

(a) Short broad spindles with many well-developed tuberculate warts arranged almost in zones. These spindles are  $\cdot 24$ – $\cdot 352$  mm. long and  $\cdot 044$  mm. wide.

(b) Smaller spindles  $\cdot 176 \times \cdot 028$  mm. having rounded spines.

The colony is female, for many rounded ova up to  $\cdot 28$  mm. in diameter are present in the upper canals. The central part of each ovum appears as a dense mass due to the presence of yolk-granules.

This specimen resembles *Sarcophytum acutangulum* in the following characters :—

(1) Shape of the capitulum with its high folds.

(2) Thin hard capitulum.

(3) Form of spicules, especially the broad spindles with zones of warts ; in this respect the specimen approaches the genus *Lobophytum*.

(4) Distribution of autozooids.

I consider the specimen to represent a new variety because of the following differences from the type as described by Kükenthal (1910) :—

(1) Spindles of the inside of the capitulum are longer.

(2) Irregular spicules on the surface of the capitulum.

(3) Tentacles are slightly shorter.

(4) In this specimen there are seven instead of nine pinnules per row.

#### SCLEROPHYTUM DURUM Pratt.

This specimen is small with a laterally compressed, cup-shaped capitulum and suggestion of marginal lappets supported by a broad sterile stalk 17 mm. long and varying from 20–12 mm. in diameter. The colony is quite hard and brittle, especially the stalk, where enormous spindles can easily be seen through the ectodermal tissues ; a white encrusting sponge also covers parts of the stalk and upper surface of the capitulum. The autozooids are small and are more numerous towards the margin of the capitulum. Each stumpy tentacle,  $\cdot 56$  mm. long and  $\cdot 315$  mm. broad at the base, has fine rounded pinnules in a lateral row at either side. I found no trace of reproductive organs in the autozooids of this colony. There are no siphonozooids. The enormous spindle-like spicules, 2.6–3 mm. long and  $\cdot 4$  mm. wide, are characteristic. They occur especially in the outer layers, and along the stalk they are arranged longitudinally. They have small tuberculate warts up to  $\cdot 09$  mm. in diameter. Towards the inside of the stalk the spindles

are of smaller size ( $\cdot 94 \times \cdot 164$  mm.), and many of them have rounded spines instead of warts. In the upper polyp body-wall the spicules are arranged parallel with the axis of the autozoid and support the base of each tentacle. The latter has a few very small smooth spindle-shaped spicules.

Previously recorded : Maldives, near Nilandu Mahlos Atoll, Addu Atoll.

### Genus DENDRONEPHTHYA Kükenthal.

The division of the genus *Spongodes* into *Dendronephtya* and *Stereonephtya* by Kükenthal aroused criticism, but an explanation is given by Shann (1912). Some writers still retain the older generic name. The genus is of wide geographical distribution in all tropical waters from depths between 8 and 45 fathoms. Hickson (1903) records its abundance in the Maldives. Kükenthal records species in cooler waters of the Japanese coast and one species from the West American coast. The classification of the genus is discussed by Hickson (1903), Kükenthal (1905), Sherriffs (1922), and Harms (1906). The latter shows the link of *Dendronephtya* with *Xenia* in the reduction of the mesenterial filaments. Sherriff's elaborate grading system and anthocodial formula does not result in any desirable simplification of the genus.

DENDRONEPHTHYA NIGRESCENS Kükth. var. ABROLHOSA, nov. (Pl. 31. fig. 7 ; Pl. 32. fig. 1.)

*Locality*.—Pelsart Island.

The colony, 66 mm. high, has a sterile white trunk 19 mm. long which gradually broadens out distally to form a flat, spreading, oval polyp-bearing area. Several equally thick, closely packed branches, the lowest of which are flattened, are given off from the trunk : these diverge many times before producing the terminal cream-coloured twigs bearing the polyps. The polyps occur in bundles consisting of six to twelve individuals, and are arranged in loose ill-defined umbels. The polyps are oval in outline, being  $\cdot 65$  mm. long and  $\cdot 58$  mm. broad. They are situated on a stalk  $1\cdot 5$  mm. long and are supported by three Stützbündel spicules up to 3 mm. long, which have very small rounded spines. The polyp spicules consist of eight double rows of spindles finely spined, each row having four pairs, with a few smaller spindles between the rows. The uppermost row of spicules protrude a little beyond the polyp head and are  $\cdot 38$  mm. long, whilst the next pair, which are more curved, are  $\cdot 315$  mm. long, the lowest pair being only  $\cdot 25$  mm. long. The tentacles, which show only a suggestion of pinnules at the distal end, are well supplied with spicules in this region. There are eight pairs of spicules in every tentacle situated in two diverging rows. They are very jagged flattened structures, varying in size, the lowest pair being  $\cdot 14$  mm. long and  $\cdot 015$  mm. broad, but the upper pair only  $\cdot 033$  mm. broad,



The colony is quite flaccid due to the thin soft nature of the canal walls, there being a very few spicules in the form of small smooth spindles in the lower walls only. The surface of the lower narrower part of the trunk is thin and granular, due to the spicules being closely packed together. The majority of spicules in this region are irregular, small, spinose forms up to .126 mm. long with spines from .03–.06 mm. long. There are also some thick spindles, .189 mm. long, and club-like forms, .126 mm. long, which have well-developed tooth-like spines. The upper part of the stem wall is very thin and transparent, containing long spindle-like spicules situated fairly closely together and parallel with the main axis of the colony. These white spindles are 1.5–2.7 mm. long and .088–.159 mm. wide, and have a very faint suggestion of spines .025 mm. apart. In the end twigs some spindles are longer, reaching a length of 3.78 mm. and a width of .25 mm., with more definite rounded spines. The mesenterial filaments, with the exception of the two dorsal ones, are very poorly developed. Attached to the mesentary in one polyp were young sperm-sacs, one of which was .11 mm. wide.

This specimen resembles *D. nigrescens* Kükth. (1905) in the following characters :—

- (1) There are four pairs of spicules in each double row, the uppermost of which protrude.
- (2) The size of the polyps.
- (3) The spicules of the basal wall of the trunk.
- (4) The number of polyps per bundle.

It differs in the following characters :—

- (1) Canal spicules.
- (2) Size of the tentacle spicules.
- (3) Number of Stützbündel spicules.
- (4) Colour.

The specimen also shows certain affinities with *D. florida*, which, according to Kükenthal (1905), includes Wright and Studer's species *S. corymbosa*, which is in the same group as *D. nigrescens*.

The affinities are :—

- (1) The canal walls are almost devoid of spicules.
- (2) The Stützbündel consists of more than one spicule.
- (3) The longitudinal arrangement of spicules in the upper crust.

#### DENDRONEPHTHYA FOLIFERA Pütter.

*Locality*.—Pelsart Island. One specimen.

This specimen is extremely delicate and flabby, the outer skin being transparent. It is dirty white with a few pink spicules in one of the lower branches. It is slim and tree-like, 83 mm. high, consisting of a sterile

trunk and a polyp-bearing area developed almost entirely in one plane. The main upright stem, 15 mm. in diameter, is extremely flaccid and granulated, giving origin at a height of 35 mm. to two leaf-like branches forming a collar. The branches are reflexed, thus hiding the upper part of the trunk. They again subdivide and bear polyps in small umbels, except at the margin, where they arise singly. Characteristic red spindles are confined to these branches and to the main stem immediately above the collar. From the latter the main stem continues, free from branches, for a distance of 18 mm., where it divides into an upper polyp-bearing area consisting of short cylindrical branches appearing on all sides. The walls of stem and branches above the collar are very thin, having a network of white spindle-like spicules. By repeated subdivision small twigs are produced which bear six to ten polyps which do not reach the same height, since young forms, having practically no Stützbündel, may frequently occur between the full-grown polyps. By the union of several polyp bundles at the end of a branch small umbels are produced. The polyps are white and oval ( $.75 \times .56$  mm.), set on a stalk 1 mm. long, inclined obtusely to the stem. The polyp head is well protected by spindle-like faintly-spined spicules, which are slightly curved, .18 mm. long, and are arranged in eight converging double rows with five pairs in each row. The second pair in each row is the longest, but they do not protrude beyond the polyp head. The Stützbündel consists of five to eight spindles having minute spines; the two uppermost spindles,  $1.89 \times .063$  mm., are the longest, sometimes protruding .6 mm. The few tentacle-spicules are small toothed plates, .055-.066 mm. long, arranged horizontally.

The lower trunk-wall appears granulated owing to closely packed spicules, the majority being irregular or quadriradiate forms with spines up to .05 mm. long. There are also clubs .22 mm. long, with a wide head bearing long spines. Others are slightly curved spindles having pointed tuberculate spines and measuring  $.5 \times .063$  mm., and may have long spines at one side only; also some may be irregularly branched. The spindles of the upper trunk-wall, including the red variety of the collar region, are slightly curved and taper at either end to a blunt point. They have almost a smooth outline, for the spines are very simple. The average size is  $1.57 \times .09$  mm., but a few are 2.2 mm. long and .113 mm. wide; there are short forms,  $.5 \times .04$  mm., with a smooth outline.

Previous locality: West Asiatic coast, Java Sea, Siam.

### Genus NEPHTHYA Savigny.

Kükenthal (1903) revised the genus *Nephtya* and tabulated the species into large groups. He (1910) criticises the introduction of new species, although five are new in his S.W. Australian collection. Shann (1912)

compared and contrasted *Lithophytum* (*Ammothea*), *Nephthya*, and *Spongodes*, indicating how the species in the genus *Nephthya* exhibit all gradations from forms with well-developed Stützbündel to those with poorly developed non-projecting Stützbündel spicules.

The genus is found in shallow waters of warm seas, and it is thus of interest to find two specimens in this collection.

NEPHTHYA COMPLANATA Kükth. (Pl. 34. figs. 6, 7.)

*Locality*.—Pelsart Island. One specimen.

This bush-like pale yellow colony is extremely flaccid. It is 137 mm. high, having a basal sterile trunk 40 mm. long and an upper polyp-bearing stem, which branches in the plane in which the colony is flattened. The distal portion of the trunk divides into three main branches which produce short, thick, cylindrical branches supporting the polyp-bearing lobes. The finger-shaped lobes, appearing as catkins on the upper branches, are practically all developed in the same plane. Towards the distal parts of the branches they are closely apposed, and, since there are small clusters of polyps on the branches between them, not sharply marked off from one another. In the basal parts of the branches and the main stem the lobes and small clusters of polyps are not so close together, thus leaving bare patches. The horizontal situation of the polyps suggests a transition to the *Stereonephthya*. Each polyp is placed on a very short thick stem, .6 mm. long, with the small oval head .5 mm. long, almost at right angles to the stalk. Each head is well protected by slightly curved spindle-like spicules up to .2 mm. long, arranged in double rows of five pairs per row; each spicule, especially the outermost pair in each row, has well-developed spines about .012 mm. long. The Stützbündel consists of five to six spindles up to 1 mm. long, converging towards the head of the polyp, the uppermost of which have their free ends somewhat thickened, with well-developed spines .031 mm. long pointing upwards.

The thin walls of the upper stem and branches are fairly closely packed with spindle-like spicules more or less at right angles to the main axis. The largest of these is .63 × .094 mm., with well-developed unbranched spines up to .025 mm. long. Some forms, usually .3 mm. long, are club-shaped, with their spines developed at the thickened end. The wall of the sterile basal part of the stem is closely packed with spicules, the spikes of which cause granulation. The majority of the spicules are star-shaped, exceedingly spinose, three- to five-rayed, with diameter up to .315 mm., and spines, often branched, up to .04 mm. long. These give rise to clubs, .263 mm. long, having long spines concentrated towards the broad end. There are also a few spindles, .63 × .15 mm., with spines often very much branched and reaching a length of .09 mm. Only star-shaped forms are at the extreme base. The canal walls are practically without spicules, only

a very few smooth spindles up to .5 mm. being found at the base of the colony.

This specimen agrees in all essential characters with *Nephtya complanata* Kükth., 1910.

*NEPHTHYA GLOMERATA* Th. & Simps. (Pl. 32. fig. 2.)

*Locality*.—Pelsart Island. One specimen.

This pale orange-brown colony, 102 mm. high, attached to coral, consists of a sterile trunk region, the extreme base of which is almost white, and an upper polyp-bearing branched region. The cylindrical sterile trunk is 60 mm. long and 15 mm. wide towards the base, but slightly narrower towards the distal end, where it begins to branch and bear polyps. Here it presents a glistening arenaceous appearance, possibly due to the longitudinal and transverse grooves, which give a corrugated appearance.

Only the upper branches arise laterally and all are covered with conical lobes terminating in rather a pointed manner and bearing the polyps, which are arranged in whorls. Some polyps are arranged in small groups arising directly from the surface of the main branch or sub-branch. The polyps are closely situated on the lobes and are supported on short stalks 1.25 mm. long so that their heads are inclined perpendicularly to the stalk, and the oral openings face the lobe and lie close to it. Each polyp, about 1 mm. long, is supported by four or five Stützbündel spicules, none of which project. These spicules are usually  $.5 \times .063$  mm., with very long spines, up to .044 mm., often concentrated at the upper end. The polyp body is protected by eight double rows of very spinose spicules. The tentacles have bluntly spined rods,  $.14 \times .022$  mm., arranged "en chevron" on the aboral surface.

The large circular canals in the polyp-bearing area are 2 mm. in diameter and are separated by extremely thin walls devoid of spicules. The closely packed spicules in the outer walls of the trunk and branches which cause the roughness support the colony. The majority are irregular tri- or quadriradiate forms with well-developed spines up to .0126 mm. long. A few are almost club-like, .189 mm. long, and there are a very few spindles,  $.441 \times .081$  mm., with spines .025 mm. long. In the outer wall of the branches the spicules are mostly spindles of all sizes, with well-developed spines as long as .037 mm., which may be branched and often are more developed on one side of the spindle. One spindle,  $.819 \times .126$  mm., has branched spines .05 mm. long, but the average size is  $.441 \times .107$  mm. There are also some irregular forms and a few clubs with spines developed at one end of the trunk-wall.

The only difference from *N. glomerata* Th. & Simps. is in the slight projection of the Stützbündel spicules in this specimen.

Previous locality: Gaspar Straits, east coast of Sumatra.

*Note on the Genera Eunephthya and Gersemia.*

*Eunephthya* and *Gersemia* are closely associated both morphologically and in respect of their habitat. The history of both genera is complicated, and there is still much difference of opinion with regard to their diagnostic characters. Kükenthal (1896) abandoned the generic name *Eunephthya* for that of a more elastic genus, which he called *Paraspongodes*; this was adopted by May (1900). Studer (1901) retained both the terms *Eunephthya* and *Paraspongodes*. The former included specimens with non-retractile polyps and the latter included those with retractile polyps and a well-developed coenenchym (i. e., the *Eunephthya alcyoniformes* in later classifications). Later Kükenthal (1903) followed the rule of nomenclature and reverted to the original name, *Eunephthya*. He (1906) divided the genus into two genera, but differently from Studer. Forms in which the polyps have a calyx he termed *Gersemia*, and those without one he termed *Eunephthya*. He (1907) divided this genus *Eunephthya* into two groups, the *Alcyoniformes* and the *Nephthyiformes*. Molander (1915) revised the genus *Gersemia*, and argued that *Gersemia* (sensu Kükenthal) cannot be considered as a legitimate genus. Molander criticised Kükenthal's use of the calyx as a distinction between *Eunephthya* and *Gersemia*; he maintained that the calyx is not to be relied on as a means of differentiation between genera or species because it is subject to actual individual variation. He also discussed the canal system in *Eunephthya* and *Gersemia*, and proved that a direct canal system is not a constant character of *Gersemia* (sensu Kükenthal). Although he rejected the genus *Gersemia* as proposed by Kükenthal, he came to the conclusion, after the investigation of *Eunephthya* (Kükth.) and *Gersemia* (Kükth.), that the genus *Eunephthya* (sensu Kükth.) should be divided into *Gersemia* Marenzeller, identical with *Eunephthya alcyoniformes* (Kükth.), and *Eunephthya* Verrill, identical with *Eunephthya nephthyiformes* (Kükth.). The characters distinguishing the *Nephthyiformes* and *Alcyoniformes* are sufficient for the establishment of two distinct genera according to Molander. He showed from his survey of the canal system in the two genera that *Eunephthya* is developed from *Gersemia*. He also pointed out the difficulty in determining the existence of a so-called calyx in *Gersemia* and showed it to be an individual variation. Broch (1916) adopted the classification suggested by Kükenthal in 1907, and, further, added that the retractile polyps of the *Eunephthya alcyoniformes* are cylindrical, whereas the non-retractile polyps of the *Eunephthya nephthyiformes* are club-shaped. Verrill (1922), in a diagnosis of the genus *Gersemia*, referred to the calices as a generic constant character and pointed out that Molander (1915) erred in his application of the name *Eunephthya*.

On the view that the group *E. alcyoniformes* is distinct from the genus *Gersemia*, the former is represented in this collection by three new species and the latter by one new species. The *Alcyoniformes*, of which only eight species are previously recorded, provide a link with the family Alcyoniidæ; they are a transitional group between the lobose forms of the Alcyoniidæ and the

tree-like forms of the Nephthyidæ. *Eunephthya* and *Gersemia* are cold-water genera, and the majority of species recorded are from the deep waters of the Northern Arctic and Temperate zones. According to Molander they are the only two genera of the family Nephthyidæ which are found in the Northern Seas. The species of *Eunephthya* and *Gersemia* recorded from the warm waters of the Azores are uncertain; similarly, *E. maldivensis* Hickson from the tropical waters of the Maldives and *E. purpurea* Th. & Hend. are regarded as of uncertain genus. The presence of the four specimens in this collection is interesting, for it points to the fact that the fauna of the Abrolhos Islands is not entirely sub-tropical.

*EUNEPHTHYA ABROLHOSA*, sp. n. (Pl. 30. fig. 5; Pl. 31. fig. 8; Pl. 32. fig. 3; Pl. 34. fig. 8.)

*Locality*:—Wooded Island, dredged in lagoon. One specimen.

This bulky specimen, 60 mm. high, is attached by an extremely thick cylindrical stalk, 25 mm. long and 20 mm. broad, to a piece of coral. The stalk is very soft and spongy with an extremely thin smooth wall, and at a height of 25 mm. it divides into three thick lobe-like branches, through the thin walls of which the mesenteries and gonads are seen. The branches curve inwards and give off small, thick, spherical masses situated on the inner surfaces of the main branches; the stumpy appearance of these sub-branches is due to contraction.

The polyps, situated on the terminal sub-branches and inner surfaces of the main branches, are in close proximity. Many are completely expanded, the dark green wide-spreading pinnate tentacles being in contrast to the pale green of the cœnenchym of branches and stalk. In the completely extended polyps the extremely thin anthocodial wall is 3 mm. long and the stomodæum is very wide and flattened. Some polyps have the tentacles bent inwards with only the aboral surface evident, and here the upper part of the anthocodial wall has transverse rings which indicate contraction. Other polyps have the tentacles completely curved under the anthocodial wall. A few polyps have their anthocodia completely withdrawn. The anthocodial region, including the polyp body-wall and tentacles, is devoid of spicules. Young polyps are evident, situated at the junction of the sterile stalk and the polyp-bearing area. The tentacles are lancet-shaped structures, 1·32 mm. long and ·138 mm. wide at the base, with seven finger-like pinnules arranged in a lateral row on either side. They curve in towards the axis of the tentacle and gradually decrease in size towards its tip. The average length of a pinnule is ·35 mm.

Inside the stalk is a series of longitudinal canals which are separated by thin soft walls devoid of spicules, except in the extreme basal region. Here there are many long slightly curved spindles measuring from ·37–·54 mm. long and ·031–·05 mm. broad and having a suggestion of spines. Only the

wall of the stalk at the extreme base has spicules in the form of a few spindles. The canal walls, especially those of the stalk, are traversed by numerous anastomosing endodermal canals,  $\cdot 018$  mm. wide, which link together the much wider longitudinal canals.

Ova are present in considerable numbers, attached to the mesenteries in the upper parts of the longitudinal tubes, and give the appearance of bunches of grapes. The largest ovum is  $\cdot 315$  mm. in diameter.

Diagnostic characters of *Eunephthya abrolhosa* :—

- (1) The soft spongy nature of the branching colony ; this is owing to the complete absence of spicules except at the extreme base.
- (2) Tentacles with seven finger-like pinnules in a lateral row either side.
- (3) Green colour of the colony.

*EUNEPHTHYA WHITEI*, sp. n. (Pl. 30. fig. 6 ; Pl. 31. fig. 9 ; Pl. 34. fig. 9.)

*Locality*.—Wooded Island. One specimen.

This small, very soft and spongy colony, 35 mm. high, has a smooth cylindrical sterile stalk, 20 mm. long and 15 mm. broad, which is pale grey at the proximal end and gradually becomes darker towards the distal polyp-bearing region. In its bulky appearance the colony resembles more closely members of the family Alcyoniidæ than those of the family Nephthydæ.

The distal part of the stalk divides into four very small, indistinctly bluntly lobose branches, two of which are taller than the others. The polyps are closely concentrated on these swollen terminal branches. Some are completely retracted, having the anthocodial regions almost completely withdrawn, thus leaving exposed verrucæ, which are slight prominences with eight longitudinal grooves indicating the tentacles. Other polyps have the tentacles completely tucked in, leaving exposed only the anthocodia, 2 mm. long. Others, again, are partially retracted, the tentacles merely curving inwards, whilst in other forms the tentacles are completely expanded. The tentacles, broad slightly tapering structures, are  $\cdot 819$  mm. long and  $\cdot 441$  mm. broad at the base. Situated in a lateral row at either side of each tentacle are seven pinnules, small rounded protuberances,  $\cdot 13$  mm. long and  $\cdot 101$  mm. broad at the base. No spicules are present in the tentacle.

The wall of the stalk is exceedingly thin, devoid of spicules, and in the upper distal end so transparent as to enable the reproductive bodies to be seen. The interior of the stalk consists of a series of large longitudinal canals, which are separated by thin walls. No spicules are present in the canal walls except at the extreme base, where great quantities of spindles, covered with many rounded spines, occur. The longest of these spindles,  $\cdot 882 \times \cdot 132$  mm., is slightly curved, but those of the average size,  $\cdot 63 \times \cdot 088$  mm., are straight. The canal walls are traversed by a network of fine endodermal tubes,  $\cdot 018$  mm. wide, connecting together the longitudinal canals, as in the family Alcyoniidæ. Reproductive bodies similar to bunches of grapes are very profuse in the upper canals and are attached

to the mesenteries. All are ova, many of which are almost mature; the largest examined was .315 mm. in diameter, and was filled with a mass of irregular globules and granules of yolk.

Diagnostic characters of *Eunephthya whitei* :—

- (1) Resemblance in form to members of the Alcyoniidæ.
- (2) Soft spongy nature of the colony due to the presence of very few spicules at the extreme base only.
- (3) Broad tentacles with seven rounded protuberances on either side.
- (4) Grey colour of the colony.

*EUNEPHTHYA BROCHI*, sp. n. (Pl. 30. fig. 7; Pl. 31. fig. 10; Pl. 32. figs. 4, 5; Pl. 34. figs. 10, 11.)

*Locality*.—Wooded Island, dredged in lagoon. Three specimens.

Two of the specimens are more dendritic than the third, which resembles the Alcyoniidæ slightly; all are brownish yellow. The largest specimen, 70 mm. high, has a stalk 30 mm. long which divides into three smaller branches, which again subdivide into smaller thick branches terminating bluntly in a claviform manner. The surface of the base of the stalk is rough owing to a network of spicules. Higher up, the stalk becomes thin-walled and soft, and is wrinkled owing to contraction, as are the branches and sub-branches. The polyps are mostly confined to the inner surface of the main branches and of the short stumpy sub-branches. They are comparatively large, for expanded ones are 2–2.5 mm. in diameter; they are arranged singly or occasionally in small groups on the terminal branches.

The second specimen, 65 mm. high, and the smallest specimen, 20 mm. high, are similar to the largest specimen but do not branch to the same extent.

There are very few spicules in any of the specimens, and these are confined to the basal region. The wall of the base of the stalk has many spindles fairly closely packed together, the majority being parallel with the axis of the stalk. They are slightly curved, many with blunt ends, though a few are sharply pointed. They are .4–.75 mm. long and .037–.063 mm. broad, having only a suggestion of spines. The inner part of the stalk consists of a series of longitudinal canals, separated from one another by fairly thick pliable walls, which, towards the centre, are .5 mm. wide. The latter contain few smooth, slightly curved spindles up to .32 × .037 mm. In the end branches the canal walls are much thinner and contain a few spindles similar to the others; they are transversely arranged at right angles to the axis of the lobe.

The canal walls are traversed by a network of endodermal tubules, .018 mm. wide, branching in all directions and not in one plane. These tubules link together canals of two series. One includes the wide longitudinal canals, 1 mm. wide, which are continuations of the polyps and have the eight mesenteries. The other series includes endodermal canals longitudinal and



parallel with those of the polyps and having an average width in all parts of the stalk of .09 mm.; none have any vestige of mesenteries. These endodermal canals are thus an extra longitudinal canal system and are connected with the wide polyp canals by small tubules. In the thin canal walls of the polyp-bearing area the extra canal system is absent and the main longitudinal canals are in direct communication by the tubules. The polyps are situated singly on the inner surface of the branches and on the stumpy terminal branches; on the latter the polyps are closely situated, whereas on the former there is an appreciable distance between two adjacent polyps. The majority of polyps appear as large cylindrical structures with the tentacles slightly incurved. Others are completely expanded with wide-spreading tentacles; a few are withdrawn into the coenenchymal mass after the manner of species of *Alcyoniidæ*. Spicules are absent in every part of the polyp. The tentacles are long finger-like structures,  $1.8 \times .441$  mm. Each has ten pairs of pinnules situated laterally; those at the proximal end are rounded, but towards the middle they are long finger-like structures,  $.441 \times .1$  mm.; at the extreme distal end they are smaller.

The colonies are all females; ova of different sizes are present attached to the mesenteries in the upper parts of the canals.

Diagnostic characters of *Eunephthya brochi* :--

- (1) Dendritic colony.
- (2) Spicules concentrated towards the base of the colony, but a few in the upper part.
- (3) Long tentacles with ten pinnules on either side which are blunt proximally but long distally.

*GERSEMIA AUSTRALIENSIS*, sp. n. (Pl. 30. fig. 8; Pl. 32. figs. 6, 7; Pl. 34. figs. 12, 13, 14.)

*Locality*.--Dredged between Wallaby and Rat Islands. One specimen.

This very compact rigid colony, 30 mm. long, is attached to a piece of coral by the cylindrical sterile stalk, 20 mm. long and 10 mm. wide. This rough granulated stalk has longitudinal ridges stretching its entire length, and indicating the internal canals. The canal walls have few spicules which cause the stalk to be so pliable. At the distal end of the stalk is a hollow-shaped sterile capitulum with small lobe-like branches at the margin. The branches (the longest is 10 mm.) bear bundles of up to eight polyps. The monomorphic polyps, being retracted, appear as rounded verrucæ,  $2 \times 2$  mm., which are situated perpendicularly to the stalk. The wall of the unretractile part of the anthocodia is closely packed with spicules to form a calyx which protects the retracted anthocodial region bearing the tentacles. This wall is granulated owing to the presence of irregular spicules with long spines, the majority being rod-like structures up to .376 mm. long, branched at one end, where there are long pointed spines .03-.04 mm. long; other parts have rounded to tuberculate warts. There are also unbranched rod-like forms of

varying lengths, covered with a few small rounded spines, but in the largest rod,  $0.346 \times 0.02$  mm., many of the spines are tuberculate. The tentacles are all tucked in the calyx and are bluntly rounded structures,  $0.378 \times 0.189$  mm. at their origin. They show a suggestion of pinnules only towards the base and contain many zoochlorellæ. Large branched spicules with long spines are closely packed at the base and project from the sides; further up they decrease in size and become more rod-like with rounded spines, with axes parallel to the axis of the tentacle. Towards the tip they decrease in size, being  $0.052 \times 0.004$  mm., with minute rounded spines; none project in this region, thus causing a smooth outline.

The canals of the stalk, up to 2 mm. wide, are separated by thin walls containing very few spicules. Those of the polyp-bearing branches contain many more spicules arranged criss-cross and presenting the following variety:—

(a) Spindles up to  $0.252 \times 0.025$  mm., with a few rounded spines; these may be more rod-like with blunt ends.

(b) Forms similar to those in the polyp body-wall, but smaller.

(c) A variety of *b*, 0.17 mm. long, with spikes from only one side of the spindle.

(d) A few minute irregular forms with the beginnings of long spines.

The granulated appearance of the stalk is due to the closely-packed spicules, which are of four varieties, all under 0.18 mm. long:—

(a) Irregular forms showing the beginnings of longer spines at one end.

(b) Broad spindle-like forms, 0.157 mm. long, with tuberculate spines.

(c) Rods, 0.126 mm. long, with rounded tuberculate wart-like spines.

(d) Irregular quadriradiate forms with rounded to tuberculate wart-like spines.

The surface of the slightly concave capitulum is rough, due to the wall being packed with spicules of three varieties:—

(a) Many spindles with small spines (*cf.* canal walls).

(b) Many rods with spines at one end (*cf.* canal walls).

(c) A small variety of rods (*cf.* canal walls).

I found no trace of genital products.

The characteristic of the species is the long spicules, branched at one end, bearing the well-developed spikes.

### Genus AGARICOIDES Simpson.

This genus was introduced by Simpson (1905) to include specimens collected from the Indian Ocean, all of which were relegated to one species, *Agaricoides alcocki*. Simpson compares the genus with *Lemnalia* emend. Bourne. Bourne (1900) divided the genus *Lemnalia* into two groups, one of which had the anthocodia pedicellate. No drawings are given showing this stalk, nor does Bourne speak of the introversion of the anthocodia. My

specimen agrees with the characteristics of *Agaricoides* in its agariciform nature, pedicelled anthocodia, withdrawal of the anthocodial region into the verruca, which is in the form of a calyx. Each verruca, with its octagonal disc-like expansion, may be compared with the calices in species of *Sarcodictyon* and *Gersemia*, and Simpson says each is homologous with the verruca in *Mopsella* with its eight marginal lobes. Bourne (1900) says that this calyx is usually well developed in all orders of Alcyonaria except Alcyoniida.

It is of interest to note that *Agaricoides alcocki* was dredged from a depth of 40 fathoms, whereas the specimen in this collection is from shallower waters, for at the locality of Wooded Island the depth is not more than 10 fathoms. Thus the genus is represented for the first time in very shallow waters.

AGARICOIDES SIMPSONI, sp. n. (Pl. 30. fig. 9 ; Pl. 31. fig. 11 ; Pl. 32. figs. 8, 9, 10, 11 ; Pl. 34. figs. 15, 16, 17, 18.)

*Locality*.—Wooded Island. Four specimens.

These four specimens are small and blue-grey, probably young colonies, being less than 16 mm. high. Each consists of a short cylindrical sterile trunk attached to coral, and an upper polyp-bearing "pileus," suggesting a young mushroom. The largest specimen, 15 mm. long, has a stalk 7 mm. long and 9 mm. broad, which is formed by a number of longitudinal canals, the proximal regions of the polyp bodies. The canal walls are packed with spicules, as is the wall of the stalk, thus giving a rigid consistency to the trunk. The surface of the stalk appears smooth, but is a feltwork of interlacing spicules.

The rounded capitulum is closely set with octagonal discs, each of which is a verruca into which the retractile anthocodial region is withdrawn. The small rounded verrucæ, 1.25 mm. in diameter, have extremely granular walls with eight longitudinal grooves indicating the octagons. This is owing to the arrangement of the tightly-packed rod-like spicules which are "en chevron" in eight rows. Each verruca may be termed a calyx with eight pointed lobes, which are free and bend towards each other, forming a false mouth into which the retractile portion of the polyp is tucked. Below the free ends of the calices, where the wall is continuous, the rod-like spicules are at right angles to the axis of the polyp, and in the basal region of the calyx the arrangement is criss-cross, forming a feltwork, although many are parallel with the axis of the polyp. The majority of spicules in this region are fusiform rods with spined tubercles. They vary in length from .22-.25 mm., and are .03 mm. wide ; some are more strongly spined than others, with spines .011 mm. long ; others broadened out slightly at one end forming clubs. The other form of spicule in the calyx is an irregular flattened form .066 mm. long.

The retractile anthocodial region is situated on an extremely thin-walled, slender, stalk-like structure, which is brown. This stalk has very few spicules,  $\cdot 18$ – $\cdot 21$  mm. long and  $\cdot 012$ – $\cdot 025$  mm. broad, which are  $\cdot 06$ – $\cdot 12$  mm. apart and at right angles to the axis of the polyp. The distal anthocodia has the wall packed with white spicules arranged "en chevron" to form eight lobes similar to those of the calyx. From each lobe arises a tentacle which can fold inwards and is thus protected. This folding under of the tentacle is the first stage of retraction of the polyp. Each tentacle is a long pinnate structure  $1\cdot 17$  mm. long, with a lateral row of pinnules on either side. Each row consists of six long lancet-shaped bluntly pointed pinnules,  $\cdot 189$ – $\cdot 2$  mm. long and  $\cdot 062$  mm. broad at the base, full of minute oval-shaped spicules similar to those in the distal part of the tentacle. The proximal part of the tentacle contains rods  $\cdot 17 \times \cdot 126$  mm., with only a suggestion of spines. At the extreme base these rods are more or less at right angles to the tentacle axis, but gradually become parallel with the axis and diverge with increasing distance from the base. Their size decreases towards the distal end, where they are  $\cdot 11 \times \cdot 07$  mm., and they become quite smooth. Thus, when infolded over the oral aperture  $\cdot 47$  mm. wide, the basal spicules of each tentacle form a kind of lid or operculum.

The polyps in this specimen are at different stages of introversion as follows :—

(1) The stalk is expanded, and at the distal end supporting the anthocodia many of the tentacles are infolded and the oral aperture is protected by the opercula.

(2) The thin-walled stalk has partially withdrawn into the calyx or verruca as an introvert, leaving the anthocodia exposed and in apparent continuation with the calyx. The introversion is possible by the thinness of the stalk-wall and the horizontal distribution of the few spicules.

(3) The anthocodia is completely withdrawn within the thin-walled stalk, which is completely introverted within the calyx or verruca by strong bands of muscles. Thus, only the verruca with its eight calices or octagons is apparent.

The walls separating two adjacent longitudinal canals are fused and thick. They are rigid owing to the well-packed spicules, the majority of which are small, flat, irregular forms,  $\cdot 063 \times \cdot 03$  mm., with rounded spines. There are also some rods,  $\cdot 25$ – $\cdot 28$  mm. long and  $\cdot 055$  mm. broad, which have tuberculate spines.

The wall of the stalk presents a close feltwork of spicules of the following varieties :—

(a) Rods,  $\cdot 132 \times \cdot 026$  mm., with rounded to tuberculate spines similar in form to those of the calyx. Some broaden outwards at the end suggesting clubs.

(b) Flattened leaf-like irregular forms with an average width of .07 mm. Some are quadricornate, but others are more rod-like, .088 mm. long, with very small spines.

Since I found no reproductive elements in any of the specimens, I consider that these are young forms of a new species of *Agaricoides*.

In general characters, for example, the unbranched nature, the pedicelled anthocodia, and the introversion of the polyps, the specimen approaches *Agaricoides alcocki* Simp. The following differences are observed :—

(1) The form of the spicules. There are no irregular flattened forms in *Agaricoides alcocki*.

(2) The scarcity of spicules in the anthocodial stalk of the present specimen.

(3) The colour of the colony.

(4) Mine is a shallow-water form, whereas *A. alcocki* is from deeper water.

#### The Family Melitodidae, with special reference to the Genera *Mopsella* and *Acabaria*.

The five genera in this family are very similar, especially *Melitodes* and *Mopsella*, which are externally almost identical. The foliaceous club-like spicules, "Blattkeulen," are considered by Ridley (1884) to separate the genus *Mopsella* from all others, although Kölliker (1865) had not attached generic importance to them. Kükenthal (1919) attaches importance to the "Blattkeulen" in the coenenchym of *Mopsella* species, and states that some of the spiny clubs in certain species of *Melitodes* broaden out to form immature leaf-clubs. The genus *Acabaria* is closely connected with both *Mopsella* and *Melitodes* in general appearance, but the coenenchym spicules are fusiform rods and not small nodular forms typical of *Melitodes*; nor are there any "Blattkeulen."

The distribution of the family is more cosmopolitan than hitherto supposed, for members are recorded from tropical and sub-tropical waters, and from the more temperate waters of South Africa. Those from South Africa are usually dredged from depths up to 47 fathoms, whereas many of the warm-water forms are from shallower waters.

#### *MOPSELLA KLUNZINGERI* Kükth.

*Locality*.—Wooded Island. Four fragments, possibly of one colony.

There are four fragments, the largest being 70 × 60 mm., all of which have been broken at the nodes. They are possibly of the same colony, for they resemble one another exactly, both in form and colour. The coenenchym is dull brick-red, and the axis, which is very much branched in one

plane, consists of nodes and internodes. The grey nodes consist of horny material in which are embedded calcareous spicules, 2 mm. long at the base and 1 mm. long in the twigs. The internodes are bright pink, 8 mm. long at the base and 6 mm. long in the twigs; they show longitudinal grooves, which are evident on the surface of the cœnenchym. The branches, which are almost at right angles, anastomose occasionally. They bear the polyps irregularly on all surfaces except one, where the thin cœnenchym is granular.

The polyps, often as far as 1 mm. apart, are borne on red, shallow, flattened, cup-like structures, .75 mm. high. The margin of each cup is extended into eight rounded lobes. The brown polyp can be completely retracted within the cup, as is evident in all my specimens. At the base of the anthocodial region are a series of horizontally-arranged spicules situated fairly far apart with smaller spicules arranged at right angles to them and converging to eight points at the base of each of the eight tentacles. Thus, calyx lobes are formed, the points of which are in a line with the marginal lobes of the polyp cup. The red spicules are broad, flat, curved or straight spindles  $.152 \times .022$  mm. with wide rounded spines. In the first stage of retraction the tentacles are bent under the lobes, and in complete retraction the whole polyp body, including calices and tentacles, is withdrawn into the shelter of the polyp cup. This method of protection of partially and completely retracted polyps is similar to that found in *Agaricoides*.

Each tentacle, .352 mm. long, .152 mm. broad at the base, and originating from the tip of each calyx lobe, has five to six pairs of broad flattened spindles,  $.088 \times .017$  mm., which have rounded spines: these spicules are yellow to colourless and converge below towards the tip of the calyx. Towards the proximal end the tentacle is devoid of spicules, but has four pairs of pinnules, wavy in outline and .132 mm. long, in a single row at either side. The majority of spicules in the thin cœnenchym are "Blattkeulen." Many are .08–.099 mm. long, the club end, .014 mm. wide, consisting of wide-spreading leaves having slightly serrated margins. The shaft varies from .022 mm. long with one girdle of tubercles, to .066 mm. long with three to four girdles of tubercles. The colour of the foliaceous clubs is invariably yellow in the leaf area, but those with the longer shaft are tinted red. A fair proportion of spindles also occurs in the cœnenchym. Some are short broad structures, .044 mm. long, with rounded spines; others, twice as long, have warted tubercles, and a number are up to .154 mm. long, with many well-developed tubercles. In the polyp cup there are small "Blattkeulen," which have a decided reddish tinge, and thereby differ from the small variety in the cœnenchym. Red spindles with tubercles are also present. The brown nodes are filled with smooth rod-like colourless spicules with an average length of .132 mm. They are bluntly pointed at either end, and have a slight swelling in the middle.

These specimens agree in all essential characters with the species *Mopsella klunzingeri* described by Kükenthal.

*Previous Locality*.—W. Australia; in Oyster Harbour, near Albany.

*MOPSELLA KLUNZINGERI* Kükth., yellow form.

*Locality*.—Pelsart Island. One specimen.

This fragment of a colony is similar to that just recorded in the following characters :—

- (1) Form of branching of the colony.
- (2) Arrangement of the polyps.
- (3) Structure of polyps, including tentacles, pinnules, and polyp cup.
- (4) Form and size of spicules of polyp cup and of cœnenchym of branches.

It differs from the type in the following characters :—

(1) Cœnenchym yellow to orange, owing to the yellow foliaceous clubs. Also some of the spindles are yellow.

(2) The paler pink internodes.

This is, therefore, a yellow "variety" comparable with *Alcyonium digitatum* described by Hickson (1895). Locality probably determines colour in *Mopsella klunzingeri* as in *Alcyonium digitatum*.

*MOPSELLA HICKSONI*, sp. n. (Pl. 30. fig. 10; Pl. 31. fig. 12; Pl. 34. fig. 19.)

*Locality*.—Pelsart Island. One specimen.

This extensively-branched specimen, 32 mm. high and 113 mm. broad, is probably a fragment of a much larger colony, for the specimen has been broken at the basal node. The branching takes place in two parallel planes. Anastomosis takes the form of short straight connections between the horizontal branches. The latter, which end quite bluntly, originate at a node and have a cylindrical axis formed of nodes and internodes. The nodes are 3·5 mm. long towards the base of the specimen but decrease in length higher up; they are dark brown, formed of horny material packed with small rod-like calcareous spicules. The internodes are longer, being 5–6 mm. towards the base of the specimen, and are salmon-pink traversed with irregular dark streaks. They increase in length towards the distal ends. The specimen is brilliantly coloured, for the polyp cups and the cœnenchym covering the axis are deep yellow, and the polyps, which are all expanded, are red in the distal portion and white above. Thus the general effect is orange.

The polyps are situated on all surfaces of the branches except one; this bare surface exposes the granular cœnenchym covering the axis. The polyps, occurring fairly closely, are situated on yellow cups 756 mm. high, which have their margin extended into eight rounded lobes. The polyps have red spicules at the distal end, which give the red appearance to the otherwise

white polyps. The lower spicules, horizontal in position and fairly widely separated, are up to .286 mm. long and .04 mm. broad; they are flattened spindles covered with rounded spines. The upper spicules are smaller and converge towards eight points forming the calyx with its eight lobes. Each lobe, the apex of which corresponds to the tip of the lobe of the polyp cup, has four to five spicules, and protects a white tentacle .56 mm. long, which is able to fold underneath it. In the lower half are six pairs of broad, flattened, pink spindles  $.14 \times .028$  mm., which converge towards the base of the polyp. In the upper half there are six pairs of pinnules, the middle pair, .198 mm., being the longest. The cœnenchym spicules are of two varieties:—

(a) Yellow "Blattkeulen," .08–.12 mm. long, comprising an upper foliaceous part consisting of many broad-pointed leaves and a lower stalk region which culminates in a point. The stalk varies in length and also in number of whorls of tuberculate warts.

(b) Some spindles up to .11 mm. long, many being very broad and having tuberculate warts. The majority are yellow, but a few are red.

The spicules forming the polyp cups are similar to those of the cœnenchym but smaller. There are a few red-tinged spindles in this area. The nodes are packed with smooth rods, 10 mm. long, which have a central swelling.

This specimen approaches most closely *Mopsella klunzingeri* in the following:—

(1) One surface of the cœnenchym is free from polyps.

(2) The arrangement of the polyp spicules is a transverse rim below, converging above to form eight calyx lobes.

(3) The tentacles in their basal parts have spicules which converge towards the base.

It differs in the following:—

(1) The tentacle spicules are red and are larger than those of *M. klunzingeri*.

(2) Each tentacle has six pairs of pinnules.

(3) The foliaceous spicules are yellow in colour, thus giving the deep coloration to the cœnenchym.

(4) The smaller broad spindles in the cœnenchym are mostly yellow and all have well-developed tubercles.

(5) There are practically no spindle-like forms in the polyp cup.

(6) The polyps are situated much closer together.

*ACABARIA DAKINI*, sp. n. (Pl. 30. fig. 11; Pl. 32. fig. 12; Pl. 34. figs. 20, 21.)

*Locality*.—Pelsart Island. Two specimens.

Both specimens, attached to coralline, have slender branches arising at the nodes at angles of  $30^{\circ}$ – $40^{\circ}$  in one plane. There is no anastomosis between



the dichotomous branches, which are compressed from front to back and decrease slightly in diameter towards the periphery. The width of the stalk at the base is 2 mm., and on removal of the cœnenchym the axis is 1.25 mm. wide, consisting of a series of white nodes and bright red internodes equal in length, .75 mm. Higher up the internodes are 1.07 mm. long and the nodes only .095 mm., appearing as narrow whitish bracelets round the red axis. The axis of the internodes consists entirely of hard, white, calcareous material without canals, whereas the nodes are of a stiff horny nature with no spicules in their formation. The thin cœnenchym encircling the axis is deep crimson, in striking contrast to the pale yellow polyps.

The polyps, supported by rounded cups, are situated alternately in a single row down each lateral margin of the branches, causing the latter to appear serrated. The basal part of the colony is quite free from polyps for a height of 25 mm. Each rounded polyp cup is slightly curved so that one side lies opposed to the branch; hence the polyp axis lies parallel with the branch. Each has a broad flat margin .315 mm. wide, whilst at the junction with the branch the width is .126 mm. The walls are filled with flattened plate-like spicules arranged horizontally, those towards the base are red,  $.154 \times .072$  mm., and slightly longer than the dark yellow forms found towards the margin of the cup. On one side they are straight with spines in the form of tubercles: the other side is curved and has well-developed tooth-like spines. The polyps are oval because the upper tentacle-bearing parts are withdrawn into the calices, which are closely folded inwards. The calices, 2 mm. long and .132 mm. broad at the base, are formed by the arrangement of the well-packed spicules in the lower polyp body-wall into eight spicule compartments or calyx lobes. The spicules are similar to those of the cup, but smaller and pale yellow. There are from five to six spicules in each calyx lobe. Those .132 mm. long are straight and are arranged horizontally at the base: smaller and more curved forms are arranged in converging pairs towards the blunt end of each lobe, the curved side, with well-developed teeth, lying towards the outer edge of the lobe and so causing the rough jagged appearance of the calyx wall.

The majority of the red spicules of the cœnenchym are rods measuring  $.121 \times .03$  mm. One surface is quite smooth, the others being closely packed with very much branched tubercles. Other forms are very broad spindles having tuberculate wart-like protuberances arranged in two to four whorls with a whorl of incipient tubercles at each blunt end. These spicules are deep yellow,  $.1 \times .02$  mm. Smaller spindles, .055 mm. long, with only two zones of less-developed warts, are present. There are also dumb-bells .088 mm. long with well-developed tubercles at either end and a waist .022 mm. free from spines.

This specimen approaches most closely *Acaharia serrata* Ridley, recorded from the north coast of Australia, but differs in—

- (a) The rod-like spicules with the tubercles at one side.
- (b) The polyp spicules with well-developed tooth-like spines on the one side.

**The Juncellid Group with special reference to the Genus *SCIRPEARIA*.**

In the early history of this group there was much controversy with regard to its classification owing to the slight external variations of the genera, but later Studer (1878) made use of the spicules in subdividing the group. Simpson (1910) included *Otenocella*, *Ellisella*, and *Scirpearella* with *Scirpearia*, all having spicules in the form of dumb-bells and elongated double clubs.

The species *S. furcata* present in this collection shows extraordinary variability, *vide* Hickson (1905) and Thomson & Henderson (1905). Simpson (1910) included under *S. furcata* many *Scirpearia* and *Scirpearella* from the Cape, Maldives, and Ceylon, and *Juncella elongata* from the Maldives.

*SCIRPEARIA FURCATA* Hickson. (Pl. 34. fig. 22.)

*Locality*.—Pelsart Island. One specimen.

This is a complete specimen attached to a piece of coral. The main stem gives origin to whip-like branches, which in turn bifurcate and give rise to similar branches, gradually tapering to a thin hair-like distal end. The main stem is narrow, measuring 1 mm. in diameter at the base, and remains unbranched for a distance of 40 mm., where two branches are given off. One is 50 mm., which again bifurcates into two very long thread-like extensions. The other is 30 mm. and further subdivides, producing the branches. The total height of the colony is 9 cm. and the cœnenchym surrounding the densely calcareous axis is salmon-pink. Polyps, appearing as dome-shaped prominences slightly paler than the cœnenchym, are situated in longitudinal series, each consisting of two or three transverse rows leaving two distinct bare tracts on two sides. The spicules of the cœnenchym are double clubs, *i.e.*, dumb-bell shaped bodies with a distinct neck, having spines at either end. These dumb-bells are .06 mm. long and .015 mm. wide. The spines are broad pointed structures, which, in the majority of the spicules, are more numerous on one head than on the other.

This specimen is placed in the "*furcata*" group because of the following characters :—

- (1) The verrucæ are low and dome-shaped.
- (2) There are two or three longitudinal rows in each series.
- (3) The verrucæ are separated into two longitudinal series by two very distinct bare tracts.

This specimen agrees most closely with the unnamed species of *Scirpearia* described by Thomson and Henderson (1905) and also with the *Scirpearia furcata* described by Hickson (1905). The main differences from these two specimens is that the verrucæ are of paler colour than the cœnenchym and that the spicules differ from those in the (a) Maldives, (b) Ceylon, and (c) Cape collections, in that the spines are not only more pointed but often more numerous at one head.

*Previously recorded*.—Ceylon Seas, Maldives, Cape.

# LIST OF ALCYONARIANS FROM THE ABROLHOS ISLANDS AND THE WEST COAST OF AUSTRALIA.

Those marked A are from the Perth Museum.

Those marked B are from the Abrolhos Islands, 28° 30' S.—29° S.

Those marked C are from the Coast, especially the vicinity of Shark's Bay, 26° S.

Those marked D are recorded by Ridley from W. Australia, 20°–35° S. (tropical to temperate waters).

Those marked E are from off Cape Jaubert, W. Australia, 18° 56' S. (tropical waters).

## Order I. STOLONIFERA.

- B. *Sarcodictyon tropicale*, sp. n.

## Order II. ALCYONACEA.

- B. *Xenia blumi* Schenck var. *pelsarti*, nov.  
 B. „ *ternatana* Schenck var. *littoralis*, nov.  
 B. „ *depressa* Kùkth. var. *kùkenthali*, nov.  
 E. *Telesto smithi* Gray  
 C. *Alcyonium pachyclados* Klunzinger  
 B. „ *sphaerophorum* Klunzinger var. *australiensis*, nov.  
 B. „ „ „ var. *saxigena*, nov.  
 B. „ „ „ var. *littoralis*, nov.  
 B. „ *digitatum* Linn.  
 B. *Sarcophytum trocheliophorum* Marenz. var. *australiensis*, nov.  
 A. „ „ „ var. *typica* Kùkth.  
 A. „ „ „ var. *pallida* Kùkth.  
 B. „ *acutangulum* (Marenz.) var. *occidentalis*, nov.  
 C. „ „ „  
 A. „ *glaucum* (Q. G.).  
 A. „ „ var. *paupercula* Marenz.  
 A. „ „ var. *mycetoides* Gray  
 C. „ *latum* (Dana).  
 A. „ *ehrenbergi* Marenz.  
 A. „ *ehrenbergi* Marenz. var. *stellata* Kùkth.  
 C. *Telesto multiflora* Laackmann  
 B. *Sclerophytum durum* Pratt  
 B. *Dendronephthya nigrescens* Kùkth. var. *abrolhosa* nov.  
 C. „ *florida* (Esp.)  
 D. *Spongodes florida* (Esp.)

- B. *Dendronephthya folifera* Pütter  
 C, E.       "       *michaelseni* Kükth.  
 C.       "       "       "       var. *levis* Kükth.  
 B, C. *Nephtya complanata* Kükth.  
 B.       "       *glomerata* Th. & Simp.  
 C, E.       "       *aurantiaca* Verrill  
 C.       "       *digitata* Wr. & Stud.  
 C.       "       *granulata* Kükth.  
 C.       "       *hartmeyer*i Kükth.  
 C.       "       *quercus* Kükth.  
 C.       "       *rubra* Kükth.  
 C.       "       *australis* Kükth.  
 C.       "       *corallina* Kükth.  
 C. *Stereonephthya whiteleggi* Kükth.  
 C, E.       "       *armata* Kükth.  
 C.       "       *ochracea* Kükth.  
 B. *Eunephtya abrolhosa*, sp. n.  
 B.       "       *whitei*, sp. n.  
 B.       "       *brochi*, sp. n.  
 B. *Gersemia australiensis*, sp. n.  
 C. *Nephtyagorgia crassa* Kükth.  
 C.       "       *pinnata* Kükth.  
 B.       "       *aurantiaca* Kükth.  
 B. *Agaricoides simpsoni*, sp. n.  
 E, C. *Studeriotis crassa* Kükth.  
 A, C.       "       *longiramosa* Kükth.  
 A, C.       "       *mirabilis* Thomson  
 C.       "       *semperi* (Stud.)

## Order III. GORGONACEA.

## Suborder SCLERAXONIA.

- E. *Suberiopsis australis* Broch  
 E. *Titanideum njöbergi* Broch  
 E. *Alertigorgia orientalis* Ridley  
 D. *Suberogorgia suberosa* Pallas  
 B, C. *Mopsella klunzingeri* Kükth.  
 C.       "       *sanguinea* Kükth.  
 B.       "       *hicksoni*, sp. n.  
 D.       "       *textiformis* Lamarck  
 E. *Melitodes* sp. aff. *albitincta* Ridley  
 E.       "       *thomsoni* Broch  
 E.       "       *fragilis* Broch  
 E.       "       *rubrinodis* Broch  
 E.       "       *dubia* Broch  
 B. *Acabaria dakini*, sp. n.  
 C. *Clathraria akalysz* Kükth.

## Suborder HOLAXONIA.

- B. *Scirpearia furcata* Hickson  
 E.       "       *pectinata* Pallas

- D, E. *Juncella juncea* Pallas
- D.       " *gemmacea* Edw. & Haime
- D. *Ellisella calamus* Studer
- D. *Ctenocella pectinata* Pallas
- E. *Plumarella pinna* Lamarck
- E. *Echinogorgia* sp. aff. *pseudosassopo* Külliker
- C. *Euplexaura albida* Kükth.
- E.       " *flabellata* Broch
- E.       " (?) *kükenthali* Broch
- C. *Plexaura michaelsoni* Kükth.
- C.       " *rigida* Kükth.
- C.       " *simpler* Kükth.
- C.       " *filiformis* Kükth.
- E. *Plexauroides mikrodentia* Broch
- E.       " *heterospiculata* Broch
- E.       " *mjöbergi* Broch
- E.       " *multispinosa* Broch
- E.       " (?) *monocanthus* Broch

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## EXPLANATION OF THE PLATES.

## PLATE 30.

- Fig. 1. *Sarcodictyon tropicale*, sp. n.  $\times \frac{3}{4}$ .
2. Part of *Sarcodictyon tropicale*, sp. n.  $\times 1\frac{1}{4}$ .
3. *Xenia depressa* var. *kükenthali*, nov.  $\times \frac{1}{2}$ .
4. *Alcyonium sphaerophorum* var. *saxigena*, nov.  $\times \frac{1}{2}$ .
5. *Eunephthya abrolhosa*, sp. n.  $\times \frac{1}{2}$ .
6. *Eunephthya whitei*, sp. n.  $\times \frac{3}{4}$ .
7. *Eunephthya brochi*, sp. n.  $\times \frac{1}{2}$ .
8. *Gersemia australiensis*, sp. n.  $\times 1$ .
9. *Agaricoides simpsoni*, sp. n.  $\times 1\frac{1}{2}$ .
10. *Mopsella hicksoni*, sp. n.  $\times \frac{1}{2}$ .
11. *Acabaria dakini*, sp. n.  $\times \frac{1}{2}$ .

## PLATE 31.

- Fig. 1. *Alcyonium sphaerophorum* var. *australiensis*, nov. Tentacle showing pinnules and spicules.  $\times 50$ .
2. *Alcyonium sphaerophorum* var. *saxigena*, nov. One tentacle showing pinnules.  $\times 37$ .



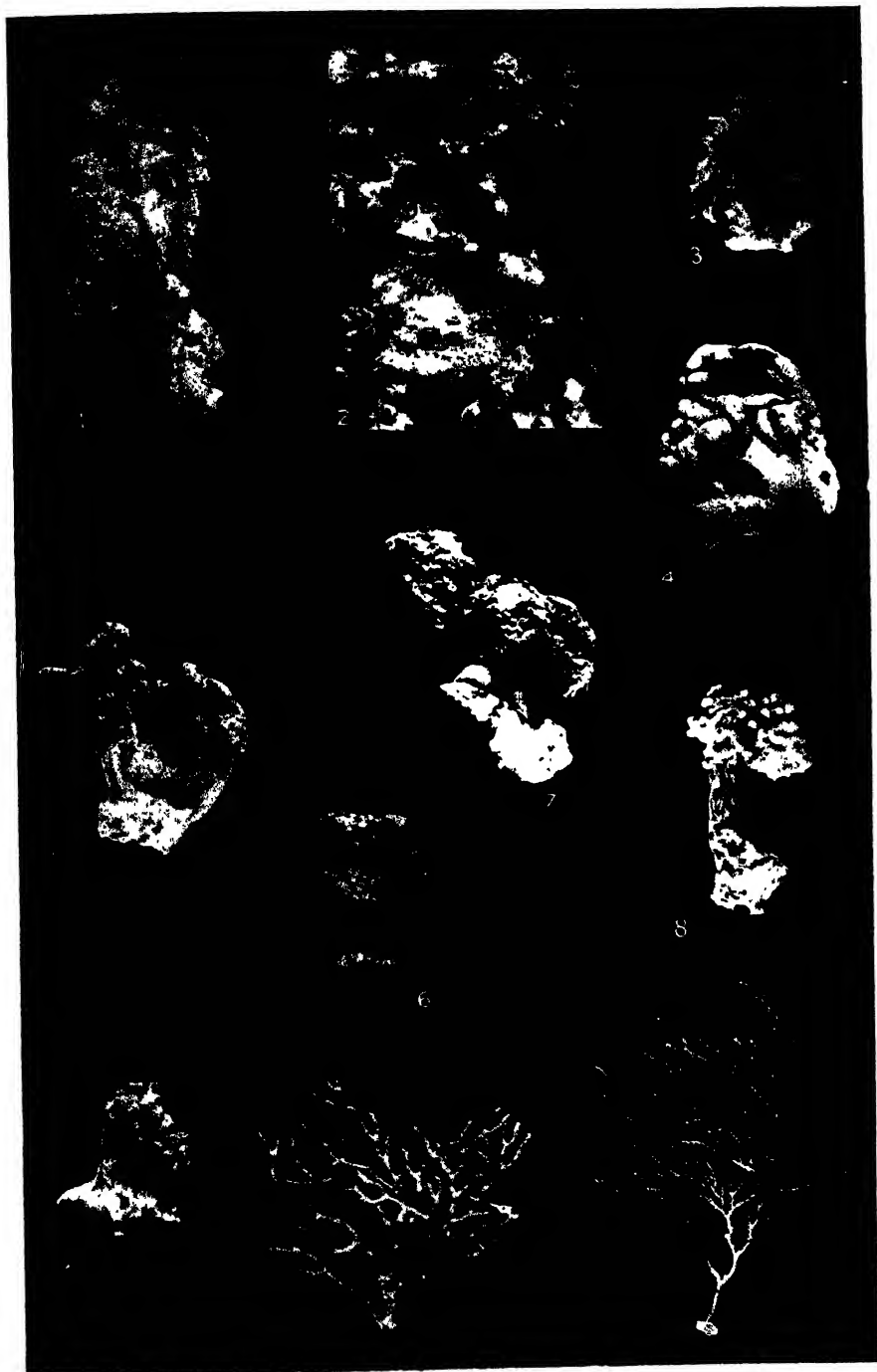
- Fig. 3. *Alcyonium sphaerophorum* var. *littoralis*, nov. Tentacle showing spicules on aboral surface.  $\times 50$ .
4. *Alcyonium digitatum* Hicson. One tentacle showing pinnules.  $\times 50$ .
5. *Sarcophytum trocheliophorum* var. *australiensis*, nov. Crown and tentacles.  $\times 50$ .  
 (a) Oral surface of tentacle.  
 (b) Side of tentacle showing aboral supporting spicules.
6. *Sarcophytum acutangulum* var. *occidentalis*, nov. Tentacle.  $\times 50$ .
7. *Dendronephthya nigrescens* var. *abrolhosa*, nov. Upper part of tentacle showing spicules.  $\times 94$ .
8. *Eunephthya abrolhosa*, sp. n. One tentacle.  $\times 38$ .
9. *Eunephthya whitsei*, sp. n. One tentacle.  $\times 38$ .
10. *Eunephthya brochi*, sp. n. One tentacle showing pinnules.  $\times 38$ .
11. *Agaricoides simpsoni*, sp. n. One tentacle.  $\times 50$ .
12. *Mopsella hicksoni*, sp. n. Calyx and tentacles.  $\times 50$ .  
 (a) Calyx; (b) Tentacles: showing (s.) spicules, (p.) pinnules.

## PLATE 32.

- Fig. 1. *Dendronephthya nigrescens* var. *abrolhosa*, nov. One polyp.  $\times 50$ .
2. *Nephthya glomerata*. One polyp.  $\times 38$ .
3. *Eunephthya abrolhosa*, sp. n. Wall of canal showing network of endodermal tubules.  $\times 38$ .
4. *Eunephthya brochi*, sp. n. Surface view of canal wall showing anastomosing endodermal tubules.  $\times 50$ .
5. *Eunephthya brochi*, sp. n. Transverse section of canal walls showing—  
 (a) Endodermal tubules; (b) Longitudinal endodermal canal; (c) Polyp canal; (d) Mesentery; (e) Gonad.  $\times 38$ .
6. *Gersemia australiensis*, sp. n. One polyp showing calyx.  $\times 13$ .
7. " " sp. n. One tentacle showing arrangement of spicules.  $\times 50$ .
8. *Agaricoides simpsoni*, sp. n. One polyp partially retracted.  $\times 10$ .  
 (a) Calyx-unretractile part; (b) Triangular lobe; (c) Tentacle.
9. *Agaricoides simpsoni*, sp. n. One polyp expanded.  $\times 13$ .  
 (a) Calyx; (b) Thin-walled stalk showing a few spicules transversely arranged; (c) Triangular lobe; (d) Tentacles; (e) Operculum.
10. *Agaricoides simpsoni*, sp. n. One pinnule showing minute ovoid spicules.  $\times 150$ .
11. " " sp. n. Diagram of triangular lobe, crown, and tentacle to show arrangement of spicules.  $\times 38$ .
12. *Acubaria dakini*, sp. n. Polyp from above showing eight calyx lobes.  $\times 50$ .

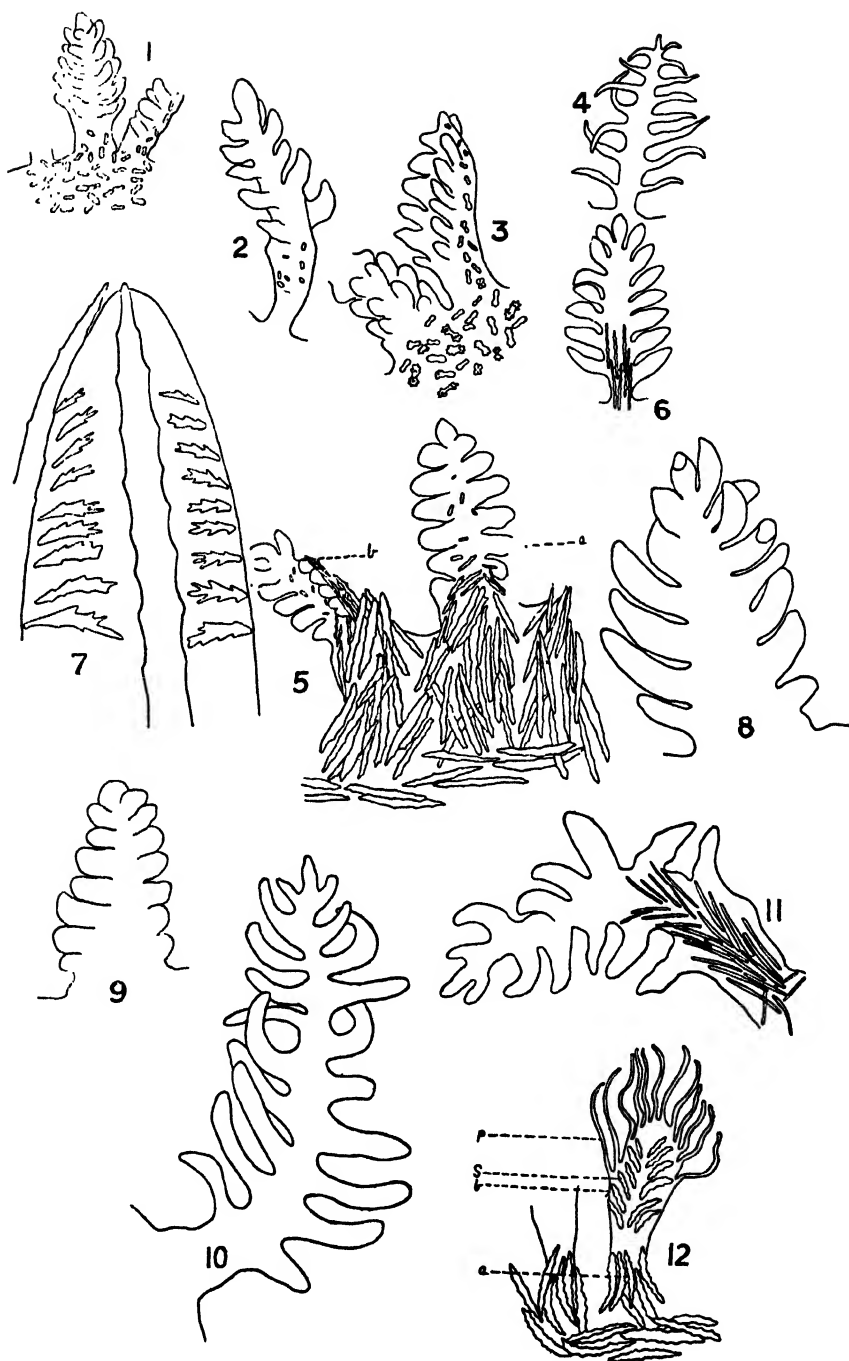
## PLATE 33.

- Fig. 1. *Sarcodictyon tropicale*, sp. n. Tentacle showing pinnules and minute calcareous bodies.  $\times 94$ .
2. *Xenia blumi* var. *pelsarti*, nov. Young form with beginnings of tentacles and small calcareous spicules.  $\times 38$ .
3. *Xenia blumi* var. *pelsarti*, nov. Inner surface of dissected young form showing two long tentacles and two minute tentacles. *m* = mesentery.  $\times 38$ .
4. *Xenia blumi* var. *pelsarti*, nov. Young form with tentacles showing:—  
 1. Suggestion of pinnules at the tip of the longest one.  
 2. The tentacles are of different length.  
 3. Distribution of minute calcareous spicules.  $\times 38$ .
5. *Xenia blumi* var. *pelsarti*, nov. Tentacle of young form showing one lateral row of pinnules at the proximal end and the beginning of a row in the distal region.  $\times 38$ .



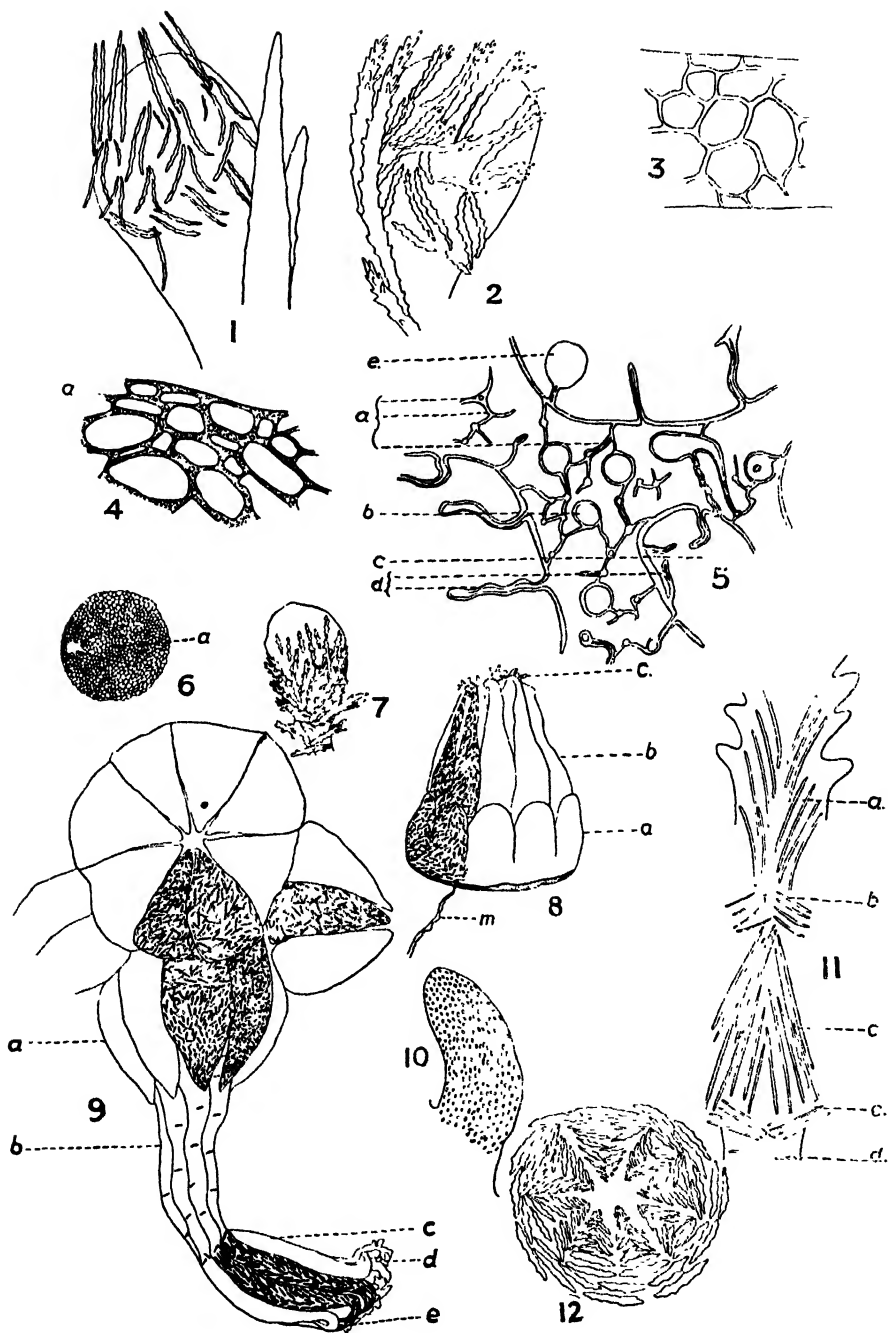
ALCYONARIA OF THE ABROLHOS ISLANDS.





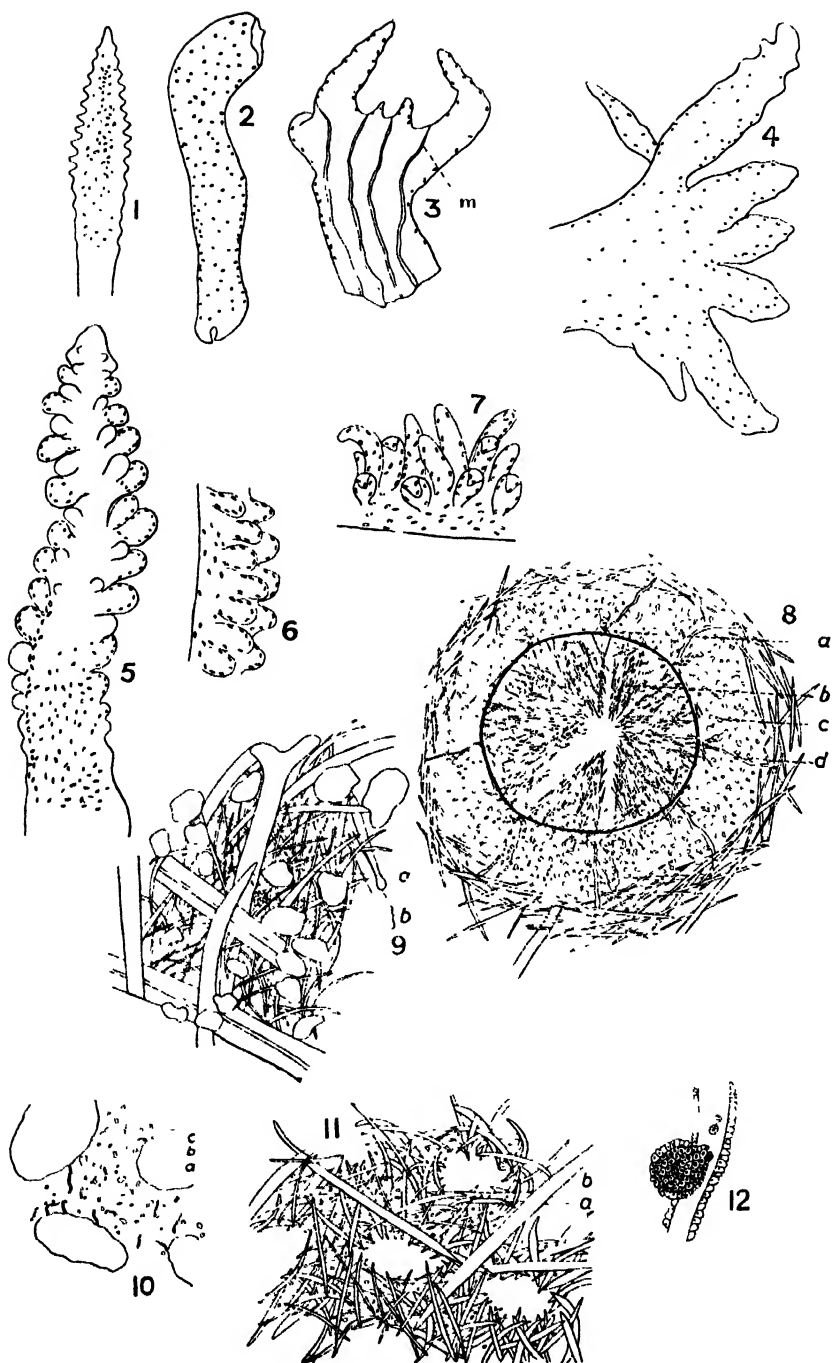
ALCYONARIA OF THE ABROLHOS ISLANDS





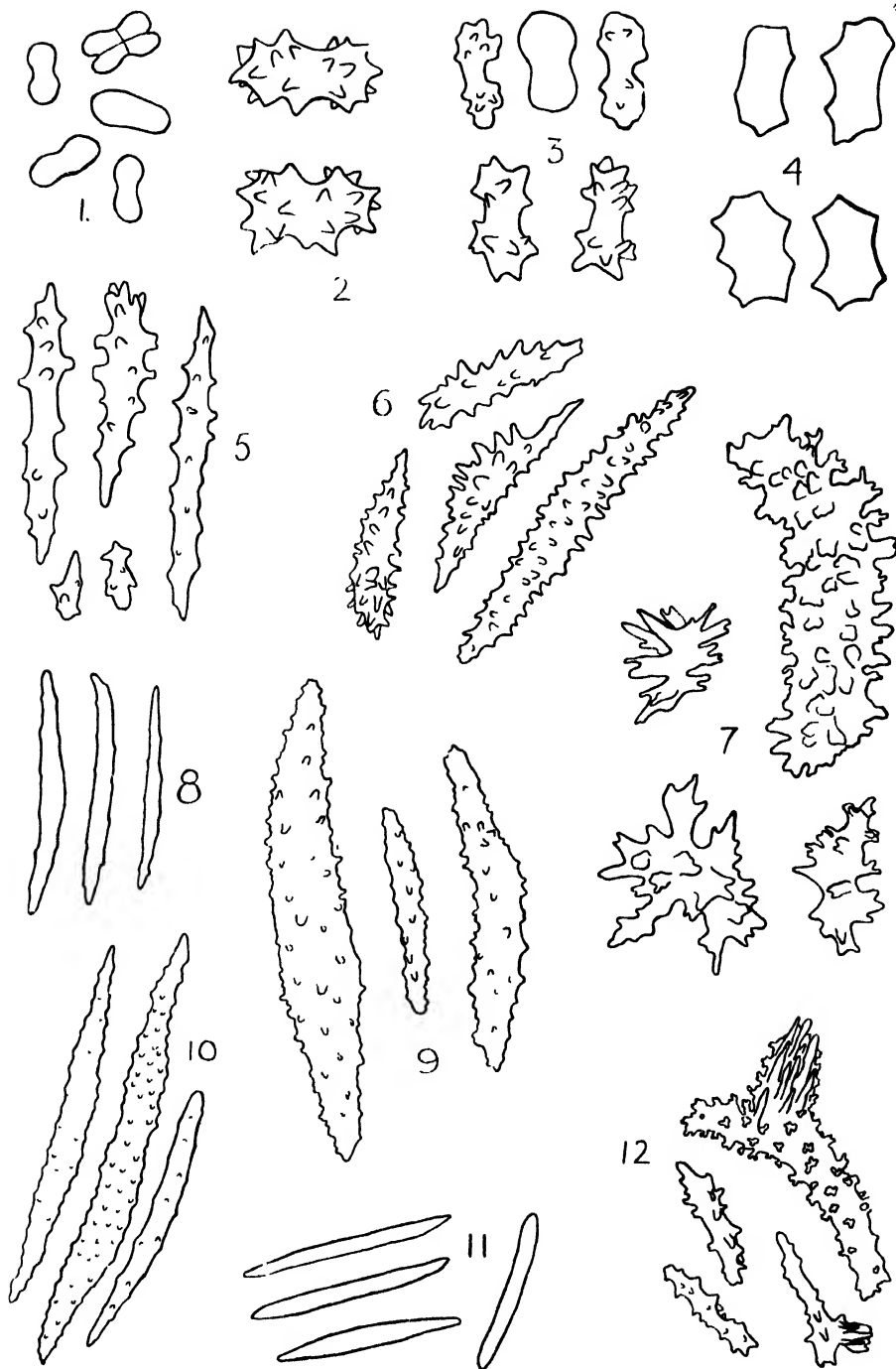
ALCYONARIA OF THE ABROLHOS ISLANDS.

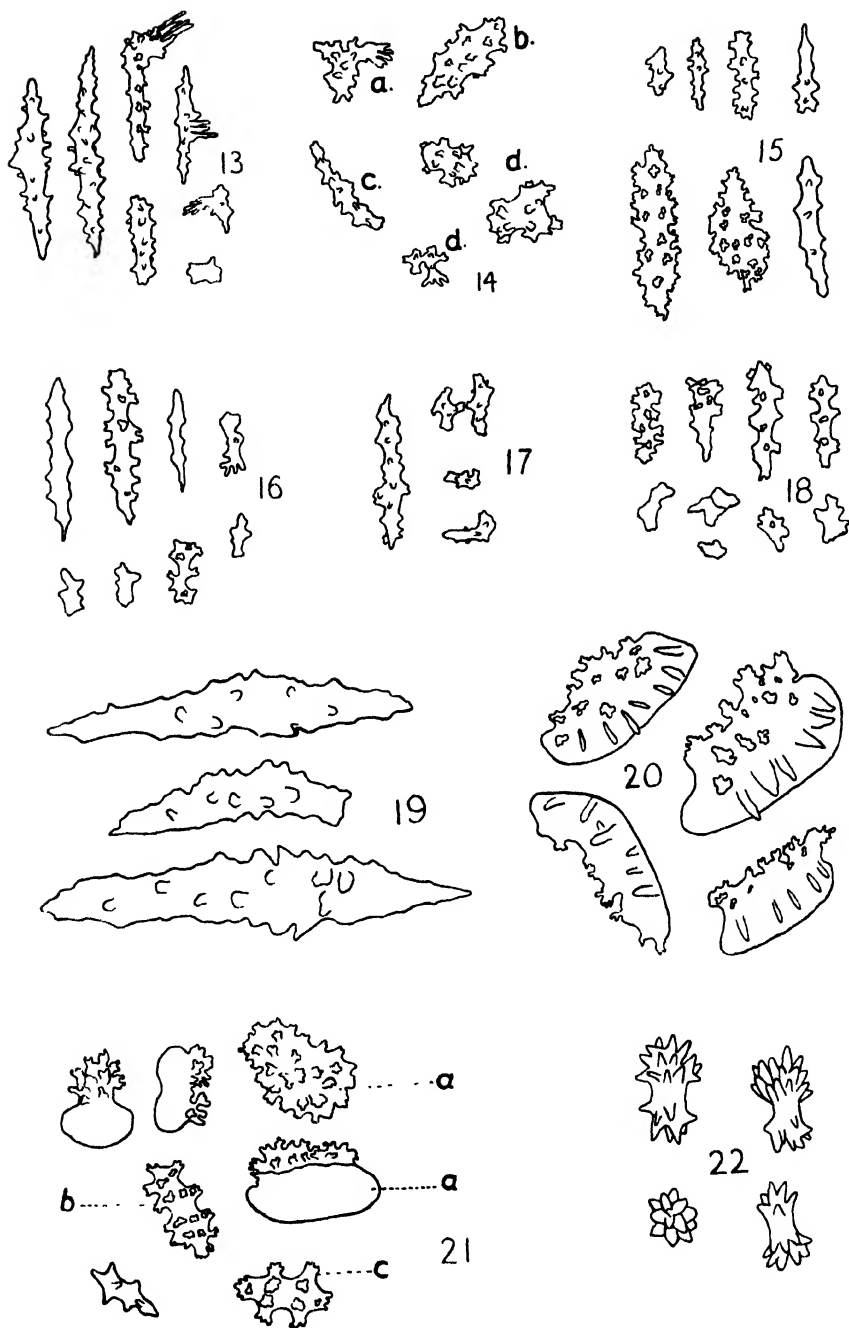




ALCYONARIA OF THE ABROLHOS ISLANDS.







ABROLHOS ISLANDS.



- Fig. 6. *Xenia blumi* var. *pelsarti*, nov. Part of one side of a young tentacle showing three rows of bluntly-rounded pinnules.  $\times 38$ .
7. *Xenia blumi* var. *pelsarti*, nov. Part of one side of a fully-developed tentacle showing three rows of long pinnules.  $\times 38$ .
8. *Sarcodictyon tropicale*, sp. n. Under surface of one polyp showing :—  
(a) Anthocodial ring with tentacles; (b) Calyx lobes; (c) Spicules of polyp; (d) Mesenteries.  $\times 50$ .
9. *Sarcodictyon tropicale*, sp. n. Surface-layer of stolon showing :—  
(a) Calcareous spicules; (b) Silicious spicules.  $\times 94$ .
10. *Sarcodictyon tropicale*, sp. n. Middle layer of stolon without silicious spicules showing :—(a) Mesogloea with minute calcareous bodies; (b) Endodermal tubule in mesogloea; (c) Lacunae.  $\times 160$ .
11. *Sarcodictyon tropicale*, sp. n. Middle layer of stolon showing :—(a) Mesogloea packed with silicious sponge-spicules and a few minute calcareous spicules.  $\times 160$ .
12. *Sarcodictyon tropicale*, sp. n. Transverse section of mesentery showing :—  
(a) One young sac; (b) Genital cell with reticulate protoplasm.  $\times 150$ .

## PLATE 34.

- Fig. 1. *Alcyonium sphaerophorum* var. *australiensis*, nov. Spicules of surface of capitulum.  $\times 225$ .
2. *Alcyonium sphaerophorum* var. *australiensis*, nov. Spicules from outside wall of stalk.  $\times 225$ .
3. *Alcyonium sphaerophorum* var. *saxigena*, nov. Spicules from inside of capitulum.  $\times 225$ .
4. *Alcyonium sphaerophorum* var. *littoralis*, nov. Spicules of surface of capitulum.  $\times 225$ .
5. *Sarcophytum acutangulum* var. *occidentalis*, nov. Spicules from surface of capitulum.  $\times 168$ .
6. *Nephthya complanata* Kükth. Spicules of wall of upper stem.  $\times 75$ .
7. " " " Spicules of lower part of trunk wall.  $\times 75$ .
8. *Eunephthya abrolhosa*, sp. n. Spicules from inside of base of stalk.  $\times 55$ .
9. *Eunephthya whitei*, sp. n. Spicules of inside of lower part of stalk.  $\times 75$ .
10. *Eunephthya brochi*, sp. n. Spicules of wall of base of stalk.  $\times 75$ .
11. " " sp. n. Spicules of canal wall.  $\times 75$ .
12. *Gersemia australiensis*, sp. n. Spicules of outer wall of polyp.  $\times 75$ .
13. " " sp. n. Spicules of canal wall.  $\times 75$ .
14. " " sp. n. Spicules from wall of stalk.  $\times 75$ . (a) Irregular forms; (b) Broad spindle-like forms; (c) Rod-like forms; (d) Irregular quadriradiates.
15. *Agaricoides simpsoni*, sp. n. Calyx spicules.  $\times 75$ .
16. " " sp. n. Spicules of triangular lobe of retractile anthocodia.  $\times 75$ .
17. " " sp. n. Spicules of canal wall.  $\times 75$ .
18. " " sp. n. Spicules of wall of stem.  $\times 75$ .
19. *Mopsella hicksoni*, sp. n. Calyx spicules.  $\times 225$ .
20. *Acabaria dakini*, sp. n. Spicules of polyp-cup.  $\times 225$ .
21. " " sp. n. Spicules of coenenchym.  $\times 84$ . (a) Ovals with branched tubercles; (b) Spindles with whorls of tubercles; (c) Dumb-bells.
22. *Scirpearia furcata* Hickson. Coenenchym spicules.  $\times 225$ .



Collembola from Mexico. By Dr. EDUARD HANDSCHIN, a.o. Professor of Zoology, University of Basle. (Communicated by Dr. A. D. IMMS, F.L.S.)

(With 35 Text-figures.)\*

[Read 1st March, 1928.]

SINCE Folsom published in 1898 a short note on some Collembola collected in Mexico we have no further record of the group from that country. In 1924 Prof. Dampf began to collect Thysanura and Collembola from the environment of Mexico, D.F., and in the snow-region of the Tlaloc. I am greatly indebted to him for having sent me his most interesting material for determination.

The species contained in his collection and forming the subject of this article are:—

- Hypogastrura armata* Nic.
- „ *matura* Fols. var. *mexicana*, nov.
- „ *copiosa* Fols.
- Schöttella nodiseta*, sp. n.
- Xenylla nitida* Tullb.
- ? *Pseudachorutes complexus* McTi.
- Achorutes muscorum* Temp.
- „ *barberi*, nom. nov. pro *A. quadrioculata* Fols.
- Tullbergia collis* Bacon var. *mexicana*, nov.
- Proisotoma intermixta*, sp. n.
- Isotoma minor* Schöff.
- „ *viridis* Bourl.
- Tomocerus flavescens* Tullb. var. *americana* Fols.
- Isotomurus palustris* Müll.
- Entomobrya decemfasciata* Pack.
- Lepidocyrtus cyaneus* Tullb.
- Lepidocyrtinus mexicanus* Fols.
- „ *semicoloratus*, sp. n.
- Heteromurus mexicanus*, sp. n.
- Sminthurinus aureus* Reut. var. *quadrilineata* Tullb.
- „ *quadrinaculatus* Ryd.
- Ptenothrix testudineatus* Fols.

In this list it is especially interesting to note the close affinity of the Mexican fauna to the North American forms. Nevertheless, a difference is marked by the formation of several well-defined varieties of northern species in the southern territories. It is only necessary to mention *Hypogastrura matura* and *Tullbergia collis*. Four of the species (*Schöttella nodiseta*, *Proisotoma intermixta*, *Lepidocyrtinus semicoloratus*, and *Heteromurus mexicanus*) are new to science.

\* The cost of the Text-figures has been met from the Westwood Fund.

## Genus HYPOGASTRURA (Bourl.) C. B.

In the more recent publications the taxonomy of the genera *Hypogastrura* and *Achorutes* has been discussed several times. Whilst on the European continent Börner's proposition of 1906 has been adopted, American authors have strictly followed Folsom and his nomenclature. In England both *Hypogastrura* and *Achorutes* are used.

As far as I can see from the material, we have to adopt Börner's view. Templeton in 1835 created the genus *Achorutes* for the species *dubius* and *muscorum*. These forms belong to two different genera.

In 1839 the diagnosis of *Hypogastrura aquatica* Bourlet was published, which in 1842 was renamed by its author *Hypogastrura murorum*. The species has nothing to do with *Podura aquatica* L.

The diagnosis of *Achorutes* Templeton refers only to the genus later named *Neanura*. In 1841 Nicolet, the contemporary of Templeton and Bourlet, and a notable specialist of the group, gave the following diagnosis of *Achorutes*:—

“Antennes coniques, plus courtes que la tête et composées de quatre articles. Quatre yeux de chaque côté de la tête, disposés sur une ligne courbe et longitudinale. Bouche très petite, sans mandibules ni mâchoires visibles, située à l'extrémité d'une trompe conique, qui est placée sous la tête et dirigée en avant. Corps comprimé, divisé en neuf segments par des étranglements et terminé par deux gros tubercles. Pattes très courtes. Anus placé en dessous de l'extrémité de l'abdomen. Point de rainure ventrale. Point d'écailles.”

There is thus no doubt about the genus *Achorutes*. The diagnosis of *Achorutes tuberculatus* Nic. is the description of our well-known *muscorum*, and it is quite impossible to misunderstand this description of a contemporary of Templeton.

The result is that *Achorutes* exists as a well-defined genus since its publication by Templeton, and the diagnosis was further illustrated by Nicolet with drawings, so that there is no doubt about the forms belonging to it. The real type of the genus is *muscorum* Templ., the form which has often been named *Neanura muscorum*. We have now only to mention the second form of Templeton's, namely *dubius*. As Bourlet himself corrected his mistake in the conception of the species, his generic name *Hypogastrura* can be used only for the second form described by Templeton. His *Hypogastrura aquatica* is a real *Hypogastrura* and not a *Podura* in our sense.

HYPOGASTRURA ARMATA Nic., 1841.

Locality. Tlaloc; in moss. 15.6.1924.

*Hypogastrura armata* is one of the cosmopolitan forms of Collembola. It seems that the distribution in America is nearly the same as in Europe. There, *armata* lives in fungi and carcasses as well as in the fauna of snow and soil, and extreme climatic differences, heat and cold, tropical and polar

regions, are not of significance in its distribution. No morphologic differences could be observed between specimens from different parts of the world.

*HYPOGASTRURA MATURA* Fols., 1916, var. *MEXICANA*, nov. (Text-figs. 1-5.)

*Locality.* Tlaloc; summit, 15.6.1924; in plant-tufts.

*Diagnosis.* Length 0.5-0.75 mm. Colour dark blue with white spots and pale yellow extremities; pigment fine granulated. Eye-patch dark blue. Hairs scarce, short, and lying flat on the body. Ant. IV. with five olfactory hairs on the outer and four on the inner side. Retractable sense-knob somewhat excentric. Antennal organ III. consisting of sense-knobs and a strong external sense seta. Postantennal organ small, scarcely visible with four

TEXT-FIGS. 1-5.



*Hypogastrura matura* Fols. var. *mexicana*, nov.

1. Ant. III. and IV. showing Ant. org. III. and olfactory hairs. 2. Postantennal organ.
3. Claw. 4. Furca. 5. End of abdomen.

tubercles and an accessory one (Nebenhöcker). Ommatidia 8+8. Claws without tooth, but often with a small vestige of one near the apex. Lower claw with small lamella at the base. Tenant hair absent. Mucro apically hooked with broad lamella. Anal spines small, dorsally situated, papillæ one-fifth of the length of the spines, basally touching each other.

This form belongs to the group comprising *maturus* Fols., *brevispinus* Fols., and *harveyi* Fols. It differs from the first two in the shape of the mucro, the presence of small anal spines, and the single hair on the tibio-tarsus. From *harveyi* it may be distinguished by the differences in the postantennal organ and the claws. *Brevispinus* and *harveyi* are large species from 2 to 2.5 mm. length, whilst *maturus* only reaches 1 mm. Therefore the specimens from the Tlaloc are placed in close affinity to this North American species, of which they may form a geographic variety.



*HYPOGASTRURA COPIOSA* Fols., 1916.

*Locality.* Tlaloc ; in moss, 15.6.1924.

A single specimen seems to belong to this species. It is dark blue and of a length of 2 mm. The Ant. IV. has six long curved olfactory hairs and a retractile end-knob. Antennal organ III. normally with two sense-hairs and two guard-setæ. Postantennal organ with four round tubercles as large as one ommatidium. Eyes with eight ommatidia on each side. Eye-spot black. Claw with one tooth, lower claw with basal lamella. Sense-hair on the tibio-tarsus long and not knobbed. Anal spines half as long as the claw, on touching tubercles.

Hairs on each segment few, smooth, curved.

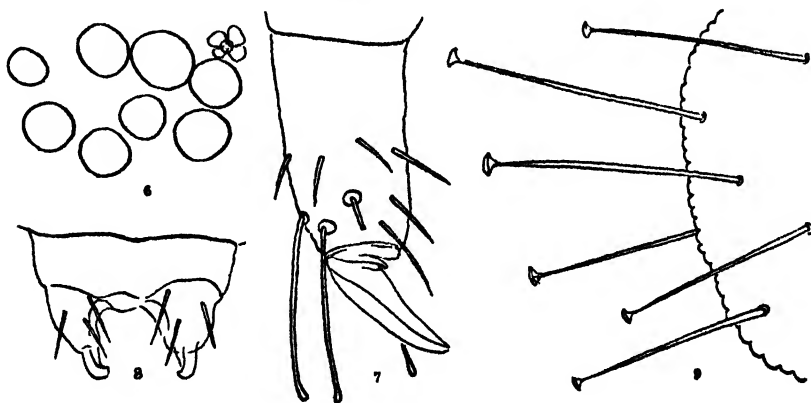
Mucro fairly hooked at the apex with a large basal lamella.

*SCHÖTTELLA NODISETA*, sp. n. (Text-figs. 6-9.)

*Locality.* Chapingo ; in mushrooms, 25.6.1924.

*Diagnosis.* Length 1.5-2 mm. Colour dark blue, ventral side somewhat lighter. Hairs short, contiguous to the body. Besides this short covering,

TEXT-FIGS. 6-9.



*Schöttella nodiseta*, sp. n.

6. Eye-patch and postantennal organ. 7. Claw. 8. Furca. 9. End of abdomen.

especially at the end of the abdomen, long, stiff, knobbed setæ. Structure of the sense-organs on Antennæ III. and IV. not observed but surely present in the usual form. Eyes 8+8 on black eye patch. Postantennal organ in a groove, consisting of four peripheral tubercles on central one, all together of the size of one omma. Mouth-parts chewing. Claw toothless, lower claw absent. Two tenant hairs on the first, three on the second and third legs. Furca small. Dentes with three bristles ; mucro simple, hooked towards the inner side, scarcely as long as claw. Anal spines absent.

The special shape of the furca combined with the appearance of the singular knobbed setæ calls for a comparison of the form with the North American *Friesea claviseta* Axels. (*sublimis* Macnamara). Having had the

opportunity to compare specimens of this species from different localities (Canada, Finland, North Germany, Switzerland), I can say that they have nothing in common with our species, which at first sight may be confounded with them. Here the presence of the postantennal organ, the chewing mouth-parts, and the absence of the unguiculus characterize the animal as belonging to *Schöttella*.

*XENYLLA NITIDA* Tullb., 1871.

*Locality.* Chapingo, 24.5.1924.

Length 1 mm. Colour bluish, pigment granulated, lighter in young individuals. Eyes 8+8 on black eye-spot. Ant. IV. with four big olfactory hairs; beside the end-knob are simple, smooth, curved, sense setæ. Antennal organ III. with two sense-knobs and two guard-setæ. Postantennal organ absent. Claw with small inner tooth, lower claw absent. Tibio-tarsus with two knobbed tenant hairs. Anal spines small. Mucro hook-like, not divided from the dentes, with broad lamella. Dentes with two bristles, the distal one reaching nearly to the apex of the mucro, the lower stumpy.

*PSEUDACHORUTES COMPLEXUS* McG., 1893.

*Locality.* Tlaloc; in moss, 15.6.1924.

The form which I identify as *complexus* McG. has a length of 0.7 mm. Colour dark blue, the pigment granulous, the legs clear, nearly colourless. Ant. I., II., III.-IV.: 11, 10, 24 (8+16). Retractable end-knob Ant. IV. somewhat excentric; eight olfactory hairs. Eyes 8+8 on dark eye-spot. Postantennal organ distinctly before the eyes, consisting of eight to nine tubercles. Mouth-parts sucking, in a projected cone. Claw without tooth, lower claw absent. Tibio-tarsus with two to three knobbed sense-hairs. Anal spines absent. Furca well developed. Mucro hook-like. Hair scarce, curved, erected.

*ACHORUTES MUSCORUM* Templ., 1835.

*Localities.* Desierto de los Leones, 12.6.1924; under bark of old trees. Chapingo, 16.6.1924.

The Mexican form shows no differences from American and European specimens of the species.

*ACHORUTES BARBERI*, nom. nov. (Text-figs. 10-11.)

Pro *Neanura quadrioculatus* (Guth.) Fols. (1903) 1916.

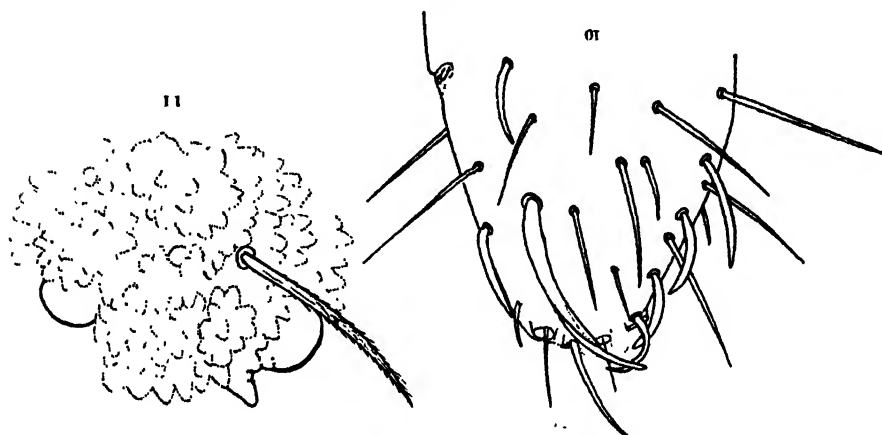
*Locality.* Desierto de los Leones, 9.12.1923.

Verifying the diagnosis, Folsom was uncertain, if the species was to be identified with *quadrioculatus* C. B. 61. In any case, Guthrie's name of the American specimens should be changed. I propose to call them *A. barberi* after the discoverer of the form.

Length 3 mm.; entirely white, skin largely tuberculated and with segmental humps, each of which bears long serrate setæ. Hairs on antennæ

and legs simple, smooth. The segmental humps are distributed in the following manner: Ant. I. 1+1; forehead 1; middle head 5, the middle formed by the fusion of two; hinder part of the head 6; Th. I. 1+1; laterally: Th. II. 5, the middle as the unpaired on the head; Th. III. 2+2; Abd. I. 3+3; Abd. III. and II. 4+4; Abd. IV. 5+5; Abd. V. 2+2, +1, the two inner parts each formed by the fusion of two, Abd. IV. 1+1.

TEXT-FIGS. 10-11.

*Achorutes barberi*, nom. nov.

10. End of antennæ. 11. Ocular tubercle.

The third and fourth joints of the antennæ fused together, their limits only marked by the Antennal organ III., which is composed of two sense-hairs, of which two on the inner side are of remarkable length. Somewhat excentric from the apex, exsertile and end-knobs and stiff setæ in a crater-like groove. Eyes 2+2, unpigmented. Claw simple, without tooth.

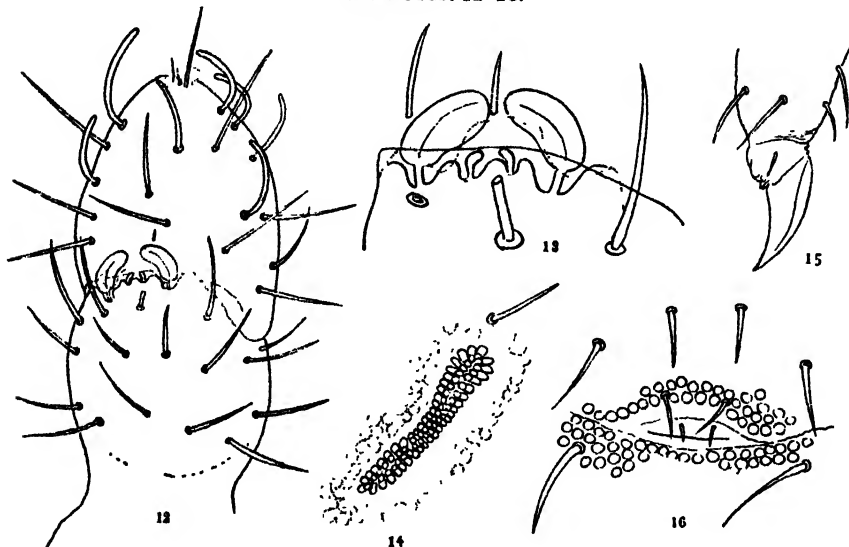
*TULLBERGIA COLLIS* Bacon, 1914, var. *MEXICANA*, nov. (Text-figs. 12-16.)

*Locality.* Tlaloc; summit, plant tufts, 15.6.1924.

*Diagnosis.* White. Length 1.5 mm. Hair long, stiff. Ant. IV. with eight large, curved, olfactory hairs, five on the inner, two on the outer side, and one dorsally. Antennal organ III. with two reniform sense-setæ, bent towards each other, between them in double groove the sense-knobs. All protected with three to four large guard-papillæ, of which the middle is the largest. Three guard-setæ are present. An accessory sense-tubercle as in *collis* Bacon could not be observed. Postantennal organ with forty to forty-five double-headed papillæ as described in *bipartita* E. H., from Switzerland and France (seen from above there seem to be eighty to ninety simple ones). Pseudocelli large, on the base of the Antennæ 1+1, hind limit of the head 1+1, Th. II.-Abd. V. 1+1—Total 18. The lamellæ of

the pseudocelli are of asterisk shape, their margins tuberculated as in *Kalaphorura*. Claw toothless, simple; lower claw small, only as bristle-like appendage. Anal spines situated on basally touching papillæ as long as the claws. Genital orifice placed transversely, armed with two setæ; two longer ones behind the organ.

TEXT-FIGS. 12-16.

*Tullbergia collis* Bac. var. *mexicana*, nov.

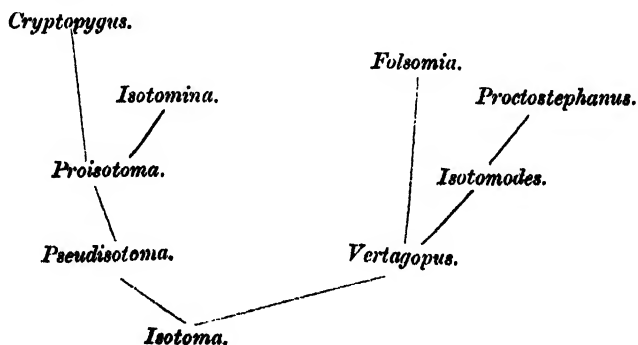
12. Ant. III. and IV. 13. Antennal organ III. 14. Postantennal organ. 15. Claw. 16. Genital orifice.

The difference between the form *mexicana* and *collis* lies in the structure of the Antennal organ III. The number of the tubercles in the postantennal organ is another difference, but as this organ always shows a great variability this difference is not essential. We cannot divide the two forms entirely, but they represent two well-defined geographic races of one species.

*PROISOTOMA INTERMIXTA*, sp. n. (Text-figs. 17-20.)

This is one of the most interesting species of the whole collection. On first examining the types, I thought that I had found in the snow regions of the Mexican mountains a real *Cryptopygus*. Only the comparison of examples of *Cryptopygus antarcticus* kindly lent me by Prof. Willem convinced me that we had to deal with a species of *Proisotoma*. As the question of the systematic position of the different genera in the Isotominae has several times been discussed, as well as the application of the generic names, I may be allowed to add here some remarks thereon. Compared with the lower families of Collembola (the Onychiuridae and Achorutidae) forms such as *Anurophorus*, *Tetracanthella*, *Folsomia*, etc., are always placed as primitive

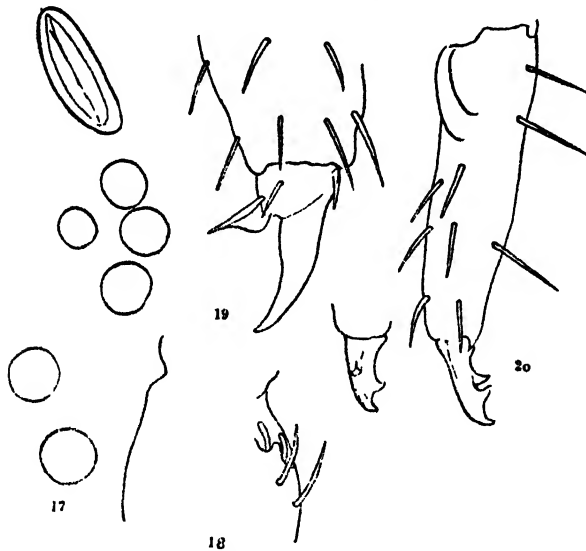
types at the base of the family of Isotomidæ. *Tetracanthella*, *Uzelia*, *Pentapleotoma*, and *Anurophorus* generally form together the subfamily of *Anurophorinæ*, showing many morphological affinities; the rest, which interest us most, are the *Isotominæ*. Here *Cryptopygus* is placed at the base, and Linnaniemi says that their affinity is much greater towards *Isotomodes* and *Folsomia* than to *Anurophorus* and *Tetracanthella*. *Anurophorus* as a totally unfurcated form holds the middle between the two subfamilies. From *Cryptopygus* are now split off the other genera of the subfamily of *Isotominæ*—in other words, *Cryptopygus* represents the oldest or most primitive type of all. A comparison of the morphology of the different forms will show whether this conception is true or not. First, we have to mention that the real primitive type of a collembolan has six nearly equal abdominal segments and vestiges of the abdominal legs are represented by the ventral tube, retinaculum, and furca. Whilst the latter are all more or less developed, the first criterion, the 6-segmented abdomen, is successively reduced in *Vertagopus*, *Folsomia*, *Isotomodes*, and *Proctostephanus*. It therefore seems probable that the forms showing the reduction in abdominal segments are not primitive, and the farther the reduction goes the farther they are to be placed from the supposed primitive base of the phylum. *Cryptopygus* has always vestiges of the sixth abdominal segment separated from the fifth, which entirely covers it. The anus is placed on the ventral side of the body. The separation of the body-segments is well defined. In *Folsomia*, *Isotomodes*, and *Proctostephanus* we also find the ventral position of the anus, but the segments are from the fourth to the end of the abdomen not distinctly divided or they are fused together. If we take this well-marked body separation and segmentation as characteristic, *Cryptopygus* has to be placed in relationship with *Proisotoma*, which also has a complete number of abdominal segments, but the same manner of reduction in the furca as the species in the *Folsomia-Isotomodes* series. Without referring to the phylogeny of the lower group (*Isotomini-Isotoma*, *Agrenia*, etc.), the systematic position of the specialised genera will schematically be drawn as in the following genealogical tree:—



*Cryptopygus* represents the youngest, most specialised form of all, which has migrated to the most exposed southern region of the globe. There the form has been transferred from the free and superficial living *Isotomini* type. The immigration into this region must be recent and the adaptation a complete and sudden one. *Cryptopygus* belongs only to the Antarctic, and at present no trace can be discovered of it in more northern parts of the southern hemisphere. The second branch of the above series is composed of forms living under bark and in the soil. In these forms the reduction of the furca and also in the number of the abdominal segments is more complete. The division of the *Isotomini* into these two different lines is therefore not only a purely morphological arrangement but also a biological one.

*Habitat.* Summit of the Tlaloc.

TEXT-FIGS. 17-20.



*Proisotoma intermixta.*

17. Ocelli and postantennal organ. 18. Antennal organ III.  
19. Claw. 20. Dens and Mucro.

*Diagnosis.* Length 0.5-1 mm. Colour from grey to black, pigment net-like, distributed over the whole body. In older individuals it forms well-defined patches. White spots on head, and especially on the anterior border of each segment. Appendages white or only feebly coloured. Eyes 6+6, black, distributed in two groups, each ommatidium separately pigmented not forming an eye-patch. Postantennal organ large, three times the length of an ommatidium. Antennæ four-jointed with typical sense-organ on the third joint. Claw without tooth, lower claw with broad inner lamellæ. Furca short, not reaching to the fore limit of Abd. III. Mucro with two

inner and one outer teeth. Anus nearly on the ventral side of the body, valvæ surrounded by the very small sixth abdominal segment.

Relative length of the body segments :—

Ant. I.	II.	III.	IV.	Head.	Th. II.	III.	Abd. I.	II.	III.	IV.	V.	Ma.	De.	Mu.
8	13	11	20	55	32	30	24	25	25	35	22	20	14	3
8	14	12	22	63	36	32	27	30	30	35	20	20	13	3
9	15	14	23	63	40	32	25	29	30	40	28	20	20	5
9	15	12	23	68	38	33	30	34	34	46	25	20	20	5
9	15	15	25	75	45	40	33	35	35	45	35	25	16	5

From these figures we note that Ant. III. is always somewhat shorter than Ant. II., the whole antenna is not quite so long as the head, and Abd. IV. is the largest of all body-segments. It is equal to Th. II.

Compared with other *Proisotoma* species *intermixta* is closely allied to *minuta* Tullb.

#### ISOTOMA MINOR Schff., 1896.

This small species is entirely white and blind with large olfactory hairs on the 4th antennal joint. It was obtained from the Tlaloc by shafting out moss.

#### ISOTOMA VIRIDIS Bourl., 1839.

The same material contained the widely-distributed *Isotoma viridis*. A careful investigation of the specimens showed complete identity with North American and European Forms.

#### ISOTOMURUS PALUSTRIS (Müll.) C. B. (1776), 1903.

*Habitat.* Desierto de los Leones, 9.12.1923. 3220 m.

The form was obtained from moss, taken from the walls of the cloister and kept moist for the culture of crane-fly larvæ.

#### TOMOCERUS FLAVESCENS Tullb., 1871, var. AMERICANA Fols., 1913.

Desierto de los Leones, region of *Abies religiosa* at 3100 mm. in mosses, 9.xii.1923. A single specimen.

As far as I can judge from Folsom's exact diagnosis, no difference between the North American and Mexican forms can be observed.

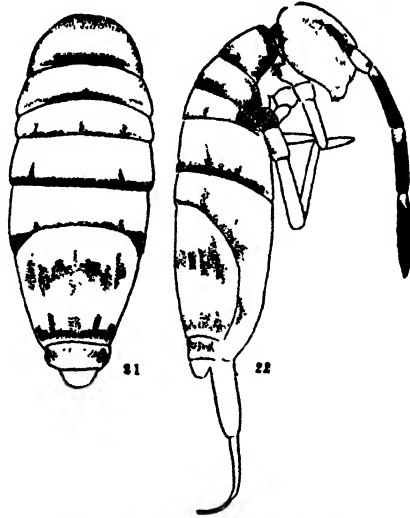
#### ENTOMOBRYA DECEMFASCIATA Pack., 1873. (Text-figs. 21 & 22.)

*Habitat.* Chapingo, 30.6.1924. On the surface of the sap in an excavation of the heart-leaves of *Agave americana*. The "Aguamiel" also contained hundreds of dead *Drosophila* and other insects. Chapingo, 30.vi.1924, under the bark of a dead *Fraxinus juglandifolius*.

The form, determined as *decemfasciata* Pack., is characterised by the number of its transverse stripes on each segment. The first is on the head, including the eye-patch, and running laterally over the cheeks. Th. II. has

two bands—one anterior, the other posterior. On Th. III. to Abd. III. only the hind borders coloured. Abd. IV. with a nearly straight stripe in the middle region. Hind margin also with broad band and Abd. V. and VI. with a stripe in the middle portion. The bands on Abd. III. follow the hind margin of the sides of Abd. IV. Abd. I. and Th. II. with lateral coloration. On all the abdominal segments are fine semilateral markings of triangular spots, perhaps forming in very dark individuals a sort of longitudinal line along the side. None of the stripes are not interrupted in the median line of the dorsum as is the case in *multifasciata* of Europe. The anterior band of Abd. IV. is straight, not excavated and semi-arched as in *multifasciata*. The characteristic side-markings of *multifasciata* are absent, and

TEXT-FIGS. 21 &amp; 22.

*Entomobrya decemfasciata* Pack.

21. View from above. 22. View from side.

both stripes are distinctly separated without the usual connection, as we find it in *nivalis* L., *muscorum* Nic., and other species. Ant. I. with basal ring and end-spot violet, Ant. II. to IV. entirely dark. On the legs only the coxæ III. of dark colour.

**LEPIDOCYRTUS CYANEUS** Tullb., 1871.

*Habitat.* Summit of the Tlaloc at about 4000 mm., 15.6.1924, under stones and in plant-tufts.

**LEPIDOCYRTINUS MEXICANUS** Fols., 1898.

Syn. *Sira mexicana* Fols.

*Habitat.* Chapultepec, 2.12.1923, under old rotten *Agave* leaves; 12.6.1924, on the border of small ditch, covered with weeds, and shadow plants.

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Chapingo, 24.5.1924, on a willow in a dried fungus (*Trames peckii* Kalchb.); 30.5.1924, under the bark of a dead tree of *Fraxinus*, the trunk being inhabited by *Calotermes*; 16.6.1924, in rotten *Agave* leaves, together with a rich fauna of Acari, beetles, and fly larvæ. Desierto de los Leones, 9.12.1924, 3100 mm., in a rotten tree.

*Lepidocyrtinus mexicanus* is one of the most abundant forms in the collection. The specimens agree completely with Folsom's diagnosis and drawings, so that I can only repeat here what he says about *L. mexicana* in his paper:—

"Usual colour blackish purple, with a conspicuous yellowish-white band on the anterior part of the fourth abdominal segment, occasionally obliterated, often every segment is banded. Head with an irregular, white, dorsal patch surrounded with purple. Eyes 8+8 on a black eye-patch. Antennæ slender, over twice as long as the head, antennal segments cylindrical, purple with pale bases, and the first and second covered with scales. Body sparsely hairy, with three clusters of clavate hairs. Mesonotum not projecting. Legs slender, the hind pair the longest, coxæ and trochanters purple, the remaining segments yellowish white, tibiæ furnished with barbellate hairs and also a single tenant hair. Claw straight, slender, tapering, and tridentate; inferior claw about half as long, broadly linear, acute, and simple. Furcula attaining the ventral tube, manubrium purple, sparsely hairy, dentes white, subequal to manubrium, slender, strongly crenulate, with stiff barbellate bristles, except at the apex of each dens, which is slender and bare, mucrones consisting of a simple slightly falcate segment. Scales varying from elliptical-oval to narrow-elliptical, thickly covered with minute lanceolate markings and having a long pedicel, Length 1.5 to 2.5 mm."

I only add, as the result of measurements, that the proportion of Abd. III.; IV. varies from 1 : 3.3 to 1 : 4.1.

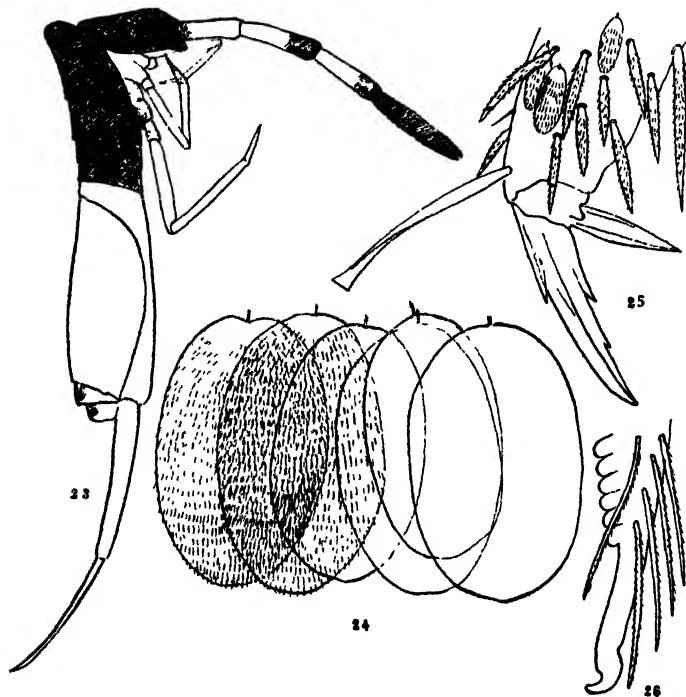
*LEPIDOCYRTINUS SEMICOLORATUS*, sp. n. (Text-figs. 23–26.)

*Habitat.* Chapultepec, 12.6.1924, in a ditch with weeds and shade plants.

*Diagnosis.* Length 2–4 mm. Body-colour (without scales) pale yellowish. Head, Th. II. to Abd. II. entirely black, also the rings on the base of the first and the apices of the second and third antennal joints. Ant. IV. dark. The coxæ, subcoxæ, and trochanters of leg III. are dark, also a small spot on Abd. V. and VI. The scales are large and brown in colour. Large individuals seem to be spotted with brown on the dorsum of Abd. IV. On the antennæ, scales could be observed up to the fourth joint. The scales themselves are rounded apically and have a fine striated structure. Bristles are totally plumose. They form probably a "Collerette" on Th. II. and an anal tuft at the end of the abdomen. Hairy bristles especially remarkable, forming two rows on either side of the annulation of the dentes, Ant. IV,

annulated, with retractile apical sense-knob. The apical part of the segment with curved plumose hairs mixed with short, stiff, naked setæ. 8+8 ommatidia on black eye-spots. Claw with two inner teeth, striated one-half and two-thirds of the length of the claw from the base. Pseudonychium large. Lower claw lanceolate, half as long as the claw. Tenant hair long and well developed. The tibio-tarsi are divided into two parts, the lower smaller, bearing the claws, one-fourth of the length of the whole part of the leg. Abd. III. to IV.=1:6.5. Mucro falciform, the annulation of the dentes suddenly interrupted and stopped.

TEXT-FIGS. 23-26.

*Lepidocyrtinus semicoloratus*, sp. n.

23. Habitus. 24. Scales. 25. Claw. 26. Mucro.

*Lepidocyrtinus semicoloratus* shows many affinities to *L. pulcher* E. H. from Brazil and *striatus* Schitt. from Queensland and New Guinea. It differs from both in the proportion of the body-segments, the form of the claws, and, most of all, by quite a different colouring.

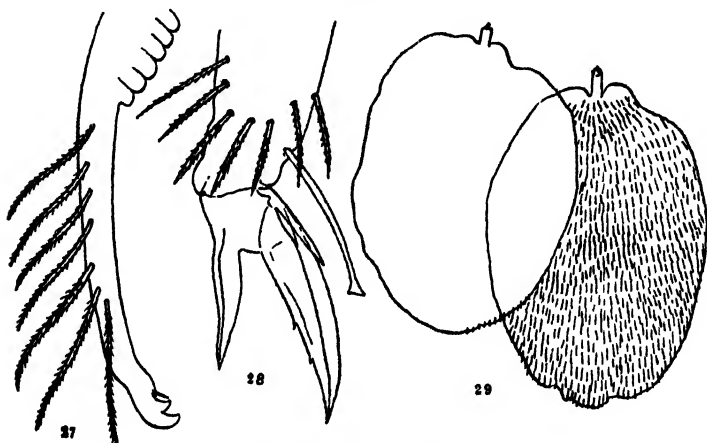
**HETEROMURUS MEXICANUS**, sp. n. (Text-figs. 27-29.)

*Habitat.* Chapingo, 30.6.1924 and 5.7.1924, under the bark of a dead *Fraxinus*, partly obtained with the Berlese apparatus.

*Diagnosis.* Length 2.5-3 mm. Body densely covered with scales. Scales rounded with irregular margins, never pointed. Dark blue pigments on

legs, antennæ (except the first joint), head (except the vertex), and on the sides of the thoracic segments. On the ventral side only a slight diffuse coloration. Annulation of the antennæ feebly marked. Ant. I. not divided into two parts as in *nitida*. Antennal organ III. of the typical structure. Eye-patch and ocellus dark blue. 8+8 ommatidia. Hair-covering scarce: a dense stiff "Collerette" on Th. II. Tenant hair short. Lower claw normal, with two inner teeth and short pseudonychium. Bristles serrate, but on the extremities mixed with smooth setæ. Mucro as in the genus *Entomobrya* with two teeth and basal spine.

TEXT-FIGS. 27-29.

*Heteromurus mexicanus*, sp. n.

27. Mucro. 28. Claw. 29. Scales.

*SMINTHURINUS AUREUS* Reut. var. *QUADRILINEATA* Tullb., 1871.

*Habitat.* Chapingo, 5.6.1924, under bark of *Fraxinus*, obtained with the Berlese apparatus.

This small well-defined variety of *Sminthurinus aureus* is yellow with two dark brown or violet lateral stripes on the sides of the body. The dark markings are also continued on the head, but there the colouring is lighter and more diffuse than on the body. Tibio-tarsus with one knobbed tenant hair. Claw with small inner tooth in middle of length. Lower claw has a knobbed appendix or filament. Mucro simple, toothless.

*SMINTHURINUS QUADRIMACULATUS* Ryd., 1878.

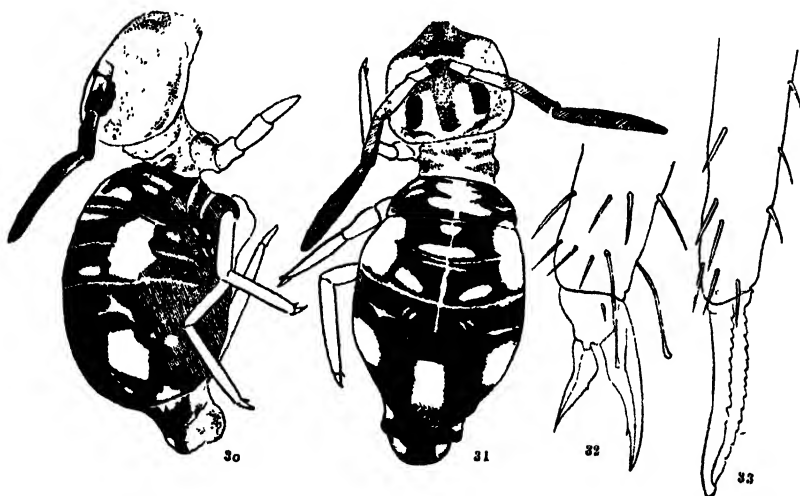
Syn. *Sminthurus quadrimaculatus* Ryder, 1878, Guthrie, 1903.

*Habitat.* Chapingo, 25.6.1924, under the bark of *Fraxinus juglandifolia*. Bark covered with a fungus. In the space between bark and wood many larvæ of *Sciariidæ* (Dipt.).

The form which I identify with *Sminthurinus quadrimaculatus* Ryd. is

extraordinarily beautiful in respect of colouring. The head is orange, dotted with brown and bistre markings. Eye-patch, ocellus, the base of the antennæ, and a triangular spot on the vertex are black. Ant. I. and II. yellow, III. and IV. dark violet. Th. II. bluish with bistre markings, the dorsum black. Towards Abd. IV. and the ventral side the black has brown and violet tints. Clear orange and yellow lines show the limits of the fused body-segments. On the dorsum a yellow median line goes to Abd. III., on both sides accompanied by regular orange spots. A large quadrangular orange spot marks the descending part of Abd. III. On either side of the abdomen two large pure white spots are characteristic of the species and

TEXT-FIGS. 30-33.

*Sminthurinus quadrimaculatus* Ryd.

30. View from side. 31. View from above. 32. Claw. 33. Mucro.

seem to be the reason for its name. Legs and spring are yellowish. Tibio-tarsus with two tenant hairs. Claw with small apical inner tooth. Lower claw with spined edge. Mucro slightly curved, serrated on both margins and rounded terminally. Anal appendage of the same structure as figured by Guthrie. Although I could not refer to Ryder's original diagnosis, it is quite evident, from comparing Guthrie's original description, that the present form is identical with his specimens.

*PTENOTHRIX TESTUDINEATUS* Fols., 1896. (Text-figs. 34 & 35.)

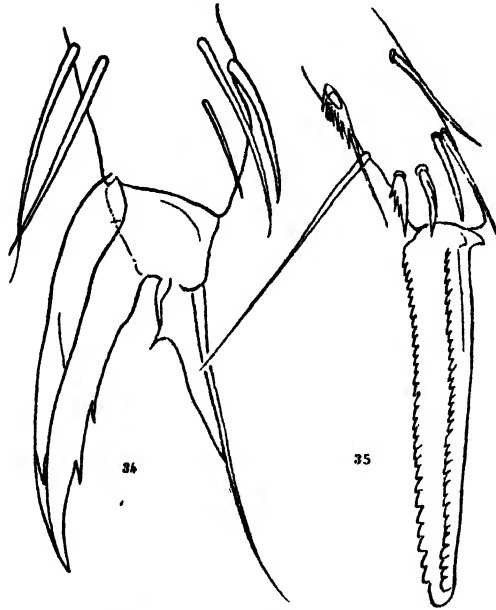
*Habitat.* Chapingo, under the bark of a dead *Fraxinus* and in fungi.

Folsom gave the exact description of this species in 1896. As it is not accompanied by drawings, those of the principal parts, the claw and the mucro, may follow here. About the species Folsom says:—

“Dark purple, almost black, with conspicuous wax-yellow patterns. Head

large, face with large markings and a few short bristles. Vertex with a few longer bristles and a stirrup-shaped mark on middle, behind this a long broken transverse band. Eyes black, antennæ seven-tenths the length of body, purplish; basal segment twice as thick as second, crenate apically; second on anterior edge of first, five times as long, somewhat petiolate, with a few hairs; third equalling first two, slightly petiolate, gradually forming false sub-segments distally, of which seven are evident, followed by three swollen ones, the penultimate sub-segment being much dilated—terminal

TEXT-FIGS. 34-35.

*Ptenothrix testudineatus* Fols.

34. Claw.

35. Mucro.

segment equal to basal in length, third and fourth segments with whorls of long hairs. Abdomen ovate dorsally with a large pattern composed principally of thick median longitudinal and oblique bars, on anterior third of dorsum, a median bar whose posterior end meets the vertices of two widely V-shaped marks, one on either side. Behind this, a roughly scissor-like pattern with two long oblique branches on either side and short median anterior lobe. On apical half of the dorsum a roughly anchor-shaped marking and two large pale yellow tubercles, one on either side; dorsum with a few long bristles anteriorly, many shorter ones posteriorly, sides with large roundish and elongated spots, anal tubercle large, with several large spots and many long stiff bristles. Legs very long, slender, hairy with broad alternate bands of purple and yellow, except on tibia. Claws white,

superior claw long, of rather uniform width, bent only towards tip, divided on the inside nearly into thirds by two prominent teeth. Inferior claw half as long, long conical, free at extreme tip but apparently prolonged into a bristle a little longer than the claw, a short bristle on inside of inferior claw at its base. Furcula long, nearly reaching the mouth, purplish. Each dens with a row of long spines on either side. Mucrones white, cylindrical, apex rounded, one-third length of dentes, serrate beneath. Length 2.2 mm."

To this diagnosis we have only to add that the tooth on the inner side of the lower claw forms an edge and that the teeth of the upper claw are situated respectively  $\frac{1}{2}$  and  $\frac{2}{3}$  the length of the claw. The spines of the dentes are serrated. It is possible that these small differences may characterize a special variety of *testudineatus* in Mexico. But as Folsom did not publish any drawings of the form, and as in all other points the Mexican specimens agree completely with the North American, I believe them to be identical.

Geographically the material collected by Prof. Dampf belong to three different regions: (1) the hot and semi-desert steppe, (2) the mountain forest, and (3) the snow region. (1) Chapultepec and Chapingo are situated near Mexico, D.F., in the cultivated region. The samples contained the forms of the lowland. It seems that the same observation has here to be made as in the case of Morocco, where I collected under nearly the same conditions. Here, as there, cultivation in the lowlands is only possible under artificial irrigation, and fauna and flora develop especially along the borders of water currents. "The vast steppes and semi-desert landscape, which only for a short time or not at all are covered with green and flowers, hinder an extension and development of forms. So insect life, and especially hygrophilous forms, are only present in cultivated terrain or near the water in parks and along the borders of water currents"\*. But where the slightest humidity, as the sap of a willow or an *Agave*, comes to the surface, or where a fungus grows, suddenly they occur and come to their food. "Whilst in moist country the richness, especially in Collembola, is very great, in dry and hot localities every specimen is a rare and welcome discovery."

They are present at the base of trees and under the moist bark of decaying trunks, but on living trees they soon disappear. At a height of 1 m. from the base only xerophilic forms are present.

The following table may show the influences of the different conditions and, compared with Tables 2 and 3, the great difference between the faunal composition in the different stations is evident (see Table I.).

In Chapultepec only *Lepidocyrtinus* has been recorded. The collection contains nine specimens of *L. mexicanus* and five of *L. semicoloratus*.

Amongst these forms we especially mention the two *Lepidocyrtinus*. This genus seems to represent here, as well as in North Africa, the most frequent

\* Translated from Handschin, 1925, p. 174.

and abundant part of the fauna. For North Africa and Southern Europe I made the observation that *Lepidocyrtus* became rarer and rarer towards the south, and that its place is soon taken by the genus *Lepidocyrtinus* with the falciform mucrones. In the north *Lepidocyrtinus* is more sporadic and always lives under quite special conditions (*L. domesticus* Nic. as a household insect; *L. dollfussi* Carl, a xerophilic species). *Lepidocyrtinus semicoloratus* has, as has been said, closely allied forms in the Brazilian *pulcher* E. H. and

Table I.—COLLEMBOLA OF THE HOT AND SEMI-DESERT STEPPE.

Locality: Chapingo. Forms	On <i>Fraxinus</i> bark.	On <i>Fraxinus</i> , base decaying.	On <i>Fraxinus</i> bark in 1 m.	On Willow, fungus.	On Willow, sap.	Under decaying leaves of <i>Agave</i> .	In fermenting sap in the centre of an <i>Agave</i> .	Localities.	Specimens.
<i>Schöttella nodiseta</i> . .		+	..	..	..	..		1	1
<i>Xenylla nitida</i> .....	..	..		..	+		..	1	Many.
<i>Achorutes muscorum</i> ....	..	..		..	..	+	..	1	3
<i>Entomobrya decemfasciata</i> .	+	..	..	..	..	..	+	2	5
<i>Lepidocyrtus cyaneus</i> ....	..	+	..	..	..			1	1
<i>Lepidocyrtinus mexicanus</i> .	..	+	+	+	..	+	..	4(5)	10(19)
<i>Heteromurus mexicanus</i> ..	+	..		..	..	..	..	1	3
<i>Sminthuridus aureus</i> var. .	+	..		..		..		1	1
<i>S. quadrimaculata</i> .....	..	+	..	..	..	..	..	1	1
<i>Plenothrix testudineatus</i> ..	+	..	..	..	..	..	+	2	10

the Australian *striatus* Schött. The three forms are somewhat aberrant in their general shape, so that it may be possible to separate them entirely from the genus. In their curious geographical distribution they have a parallel in the genus *Cremastocephalus* Schött from California. This genus also extends from North America over the Pacific and Indian Islands to Japan, and quite recently I had the chance to find in material from Costa Rica a closely allied species. Are these forms to prove, together with other invertebrates and vertebrates, the supposed connection of the Australian Continent with South America? We cannot say anything more about it. But an intensive study of the Apterygote insects of South America, especially the Andes, will give us the key to prove whether such a supposition may be probable or only a hypothesis.

(2) Desierto de los Leones is situated in the forests at 3000–4000 m. elevation. The fauna belongs also to the mountain region and begins to show a strong affinity with that of the north.

Real hygrophilous species such as *I. palustris* and *Tomocerus* occur, but still *Lepidocyrtinus mexicanus* shows that the influence of hot desert climate

runs up to the mountains. As Prof. Dampf wrote me, the dry period is from the end of autumn to the end of May. Then the vegetation is dead

Table II.—COLLEMBOLA OF THE MOUNTAIN-FOREST.

*Achorutes barberi*.  
*Achorutes muscorum*.  
*Tomocerus flavescens* var. *mexicanus*.  
*Lepidocyrtinus mexicanus*.  
*Isotomurus palustris*.

and sand-storms blow over the country. Neither under bark nor under stones are Collembola then to be found, except in the higher mountain regions. It is evident that *Isotomurus* and *Tomocerus* have not been found in lower regions, but at the same time their presence is characteristic for the more moderate mountain regions. Both are forms of moderate climate, and *Tomocerus* characterizes the moderate northern hemisphere of the globe. In the Tropics it has not so far been observed (with the exception of a specimen from the mountains of Sumatra, Weber-Oudemans).

Whilst the ratio of northern and southern species in the Mexico high plateau was 7 : 3, it increases in the forests in favour of the northern species to 8 : 2 and in the snow region of the Tlaloc to 9 : 1.

(3) Only in the highest altitudes on the summit of the Tlaloc may the Fauna be called an alpine one. Above the tree-limit, life-conditions become more and more equal in every country, from the North to the Equator and towards the South. So we are not astonished to meet there at 4000 and 4100 m. a pure Nearctic-Palæarctic fauna.

Table III.—COLLEMBOLA OF THE SNOW-REGION.

Tlaloc, above the tree-limit in Mosses, 4000 m. :—

*Hypogastrura matura* var. *mexicana*.  
*Tullbergia collis* var. *mexicana*.  
*Proisotoma intermixta*.  
*Lepidocyrtus cyaneus*.

In plant-tufts on rocky soil at 4100 m. :—

*Hypogastrura armata*.  
*Pseudachorutes complexus*.  
*Hypogastrura copiosa*.  
*Proisotoma intermixta*.  
*Isotoma minor*.  
*Isotoma viridis*.  
*Lepidocyrtus cyaneus*.

We find well-known American species mixed with a contingent of cosmopolitans, which are met with in polar regions and also under the equatorial sun of the Pacific islands, forms which belong to the fauna of the sea-shores of Europe as well as to the fauna of the highest summits of the Alps. It seems that the immigration of these forms into the region is a more recent



one, for we note that the American species are not yet entirely separated from their ancestral forms. They become only under the quite changed conditions in the highest Mexican mountains, neotendemics, similar to those we have in Europe between the northern and southern mountain regions, the Alps and the Scandinavian "Schild."

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Polychæta of the Families Polynoidæ and Acœtidæ from the Vicinity of the Panama Canal, collected by Dr. C. Crossland and Dr. Th. Mortensen.  
By C. C. A. MONRO, M.A., F.L.S.

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(With 30 Text-figures.)

[Read 29th March, 1928.]

#### INTRODUCTION.

The Polychæta collected by Dr. Cyril Crossland on the cruise of the S.Y. 'St. George' in 1923-1924 were presented by him and by the Scientific Expeditionary Research Association to the British Museum. Except for two species procured on the Atlantic side of the Isthmus of Panama, the collection was obtained in the vicinity of the Pacific mouth of the Panama Canal and the Galapagos Islands. Furthermore, Dr. Th. Mortensen, of Copenhagen, has very kindly entrusted me with the determination of a collection of Polychæta obtained by him in his Pacific Expedition of 1914-1916, and the two collections are here dealt with together.

#### Family **Polynoidæ**.

##### Genus **LEPIDONOTUS** Leach.

*LEPIDONOTUS CARINULATUS* Grube, 1878, p. 26, pl. iii. fig. 2 ; Fauvel, 1911, p. 367, fig. 1 ; Potts, 1910, p. 331 ; Horst, 1917, p. 69, pl. xv. fig. 10.

*Occurrence*. "Taboga, 5 fms." "Balboa, scrapings, coral fragments from buoy at Canal entrance." Coll. Crossland.

*Remarks*. Eighteen specimens of this species, which is common in the Indian Ocean. The average size is 7 mm. by 3 mm. including the feet. It has been recorded from the Red Sea to the Philippines, but not previously from the American coasts.

##### *LEPIDONOTUS CROSSLANDI*, sp. n.

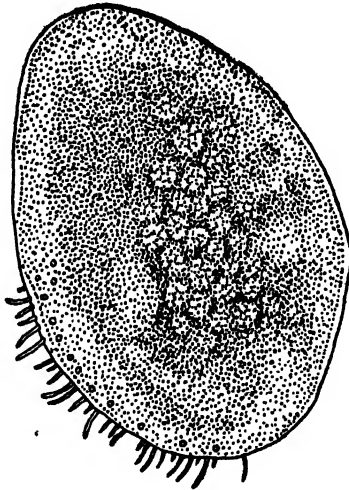
*Occurrence*. "Balboa, rocks and rock-pools." "Taboga, 5 fms., coral fragments." Coll. Crossland.

*Description*. Three specimens, the average size being 11 mm. by 3 mm. including the feet. Two have the elytra cream-coloured with a small black patch over the elyrophore and a number of paler round dots ; the third has dark grey scales with a light patch over the elyrophore.

The prostomium is divided by a long median furrow, and behind it there is a distinct nuchal fold. There is a very prominent and stout median tentaculophore, half the length of the lateral tentacles, which are themselves about half the length of the palps. The median tentacle has a very long filiform tip which extends beyond the end of the palps. The tentacular cirri have also very prominent tentaculophores, and are slightly longer than the lateral tentacles. The two pairs of eyes are situated far back on the prostomium, and are well separated.

The elytra (text-fig. 1) are sparsely fringed on the extero-lateral border and are thinly dotted with small prominences. The pigment is arranged in alveolar patches.

TEXT-FIG. 1.



*Lepidonotus crosslandi*, sp. n. Middle elytron.  $\times 35$ .

The dorsal cirri are long, reaching well beyond the bristles, and the cirrophores are bulged out on one side with a very large swelling. There are also very distinct raised ridges in the cirriferous segments corresponding to the elytophores on the elytophorous segments.

I could find no trace of branchial papillæ on the feet. The ventral cirri are very small.

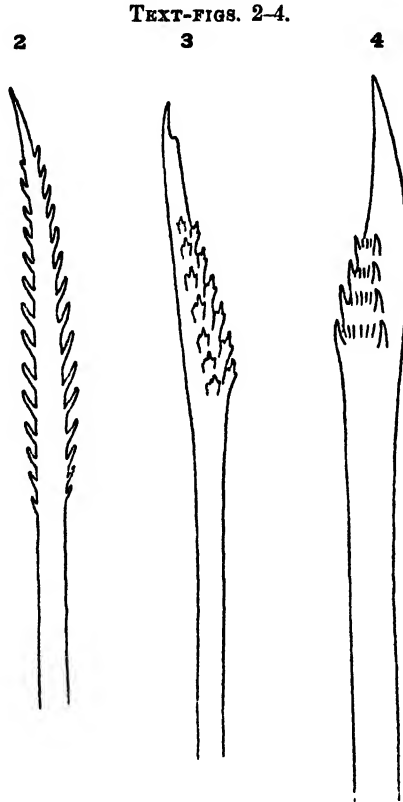
In the foot the notopodium is reduced to a small dorsal attachment of the neuropodium. In the first few segments the dorsal chæstæ are fairly numerous. They are extremely fine and of the type associated with *Euphione*. They resemble those figured for *Lepidonotus tenuisetosus* (Gravier). More posteriorly their number is reduced to about half a dozen.

In the first foot the ventral chæstæ (text-fig. 2) differ from those found in the remaining feet, as they do in *Lepidonotus carinulatus* and in *L. tenuisetosus*.

Rows of spines are continued right down the shaft, and the apex is long and curved.

In the second foot the toothing is still continued further down the shaft (text-fig. 3) than in a normal foot, and in the same chaetæ there is a distinct secondary tooth below the first. All the ventral bristles of the remaining feet are unidentate (text-fig. 4) with a very short toothed area.

*Remarks.* This species belongs to the group which includes *L. tenuisetosus*, *L. bowerbankii*, and *L. carinulatus*. It is very close to *L. tenuisetosus*, but



*Lepidonotus crosslanai*, sp. n.

Fig. 2.—Ventral chaeta from first foot.  $\times 525$ .

Fig. 3.—Ventral chaeta from second foot.  $\times 525$ .

Fig. 4.—Ventral chaeta from middle foot.  $\times 525$ .

differs in possessing smoother elytra with simple papillæ. Moreover, the tufts on the chaetæ of the first foot figured by Gravier for that species may or may not be accidental. Gravier's species has the eyes contiguous; in this species they are separated. Gravier does not record the presence of bidentate chaetæ in the second foot of *L. tenuisetosus*,

## Genus THORMORA Baird.

## THORMORA JOHNSTONI (Kinberg).

*Lepidonotus johnstoni* Kinberg, 1857, p. 12, pl. iv, fig. 13.

*Occurrence.* "Taboguilla, Panama, 5 fms. Shell." "Taboga, Panama, 4-5 fms. Sand and stones." Coll. Mortensen.—"Taboga, Panama. From dead, broken coral, dredging 1-2 fms.; and from off the Hotel pier." "James Bay, Galapagos. Weeds with tubicolous Amphipods, 5-6 fms." Coll. Crossland.

*Description.* Sixty specimens. The average size is 15 mm. by 6 mm. including the feet. This species is immediately recognisable by the difference in colour of the first two pairs of elytra from the rest, and by the

TEXT-FIGS. 5-7.

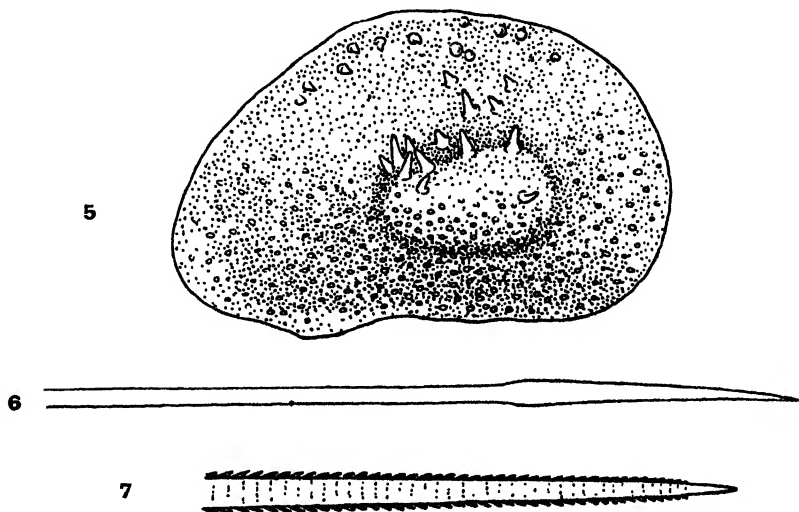
*Thormora johnstoni* (Kinberg).

Fig. 5.—Third elytron showing hooked spines.  $\times 35$ .

Fig. 6.—Spear-shaped dorsal chaeta.  $\times 115$ .

Fig. 7.—Toothed dorsal chaeta.  $\times 350$ .

presence of a dark spot on the dorsal surface of each segment. The body-colour is pale yellow in spirit, and the elytra show a wide range of variation in colour. The first two pairs are always whitish, usually with a few dark spots, and the posterior border of the second pair takes the same colour as the rest of the elytra. This colour may be anything from a light red- or chestnut-brown to a dark mottled purple.

The head corresponds to Kinberg's figure, except that the tentacular cirri usually have three black bands—a basal, a median, and a terminal; in some examples the basal and median bands are fused into one. Kinberg shows the palps as smooth; in these specimens they are distinctly hirsute,

The first three pairs of elytra (text-fig. 5) have a number of hooked spines towards the centre, and all are beset with small tubercles, such as are figured by Kinberg. The elytra are eccentrically attached. The general appearance of the feet changes very much according as the dorsal chætæ are extruded or withdrawn. Kinberg's figures of the foot and the chætæ (text-figs. 6 and 7) are not very satisfactory.

*Remarks.* Kinberg's *Lepidonotus johnstoni* was found on the "Ora insularum juxta Panama," and I think that my specimens from the type-locality may be attributed to his species in spite of certain differences. Kinberg's figure of a toothed dorsal chæta resembles neither of the two types in my specimens nor any dorsal chæta belonging to the genus.

The *Polynoe taniata* of Ehlers, which Seidler refers to *Thormora*, is very close to this species. According to Seidler it has a true lepidonotid head, and Ehlers's figures of the chætæ closely resemble those of my Panama specimens. Ehlers, however, figures the tentacles and cirri as being hirsute. In my specimens they are smooth. The *Lepidonotus versicolor* of Ehlers (1901, p. 50) is also very close to this species, but according to Seidler the spear-headed dorsal chætæ are hirsute—a fact overlooked by both Ehlers and Augener.

*Collector's Notes.* Dr. Crossland made the following notes on some living or freshly-preserved examples of this species from Taboga:—"Body uniformly chestnut-coloured, being covered with elytra of that colour, but feet are white. Dorsal cirri are white with a black band below the tip. The anterior end, as far as the first two pairs of feet, whitish with black specks, divided clearly by a black line from the brown part. This black line crosses the second pair of elytra behind the point of attachment. All chætæ stout and golden or even brown in colour.

"Later got several specimens from washings. The peculiar coloration of the head-end is constant, but some are otherwise coloured bright orange and have white spots at the attachment of the elytra."

#### Genus IPHIONE Kinberg.

IPHIONE OVATA Kinberg. Kinberg, 1857, p. 8, pl. iii, fig. 8.

*Occurrence.* "Coiba Island, Panama. Volcanic rocks and boulders." "Gorgona, coral." Coll. Crossland.—"Taboguilla, Panama. Shore under stones." "Taboga. Shore." "Tortolita, Panama: 3-5 fathoms." Coll. Mortensen.

*Remarks.* Thirteen specimens. The larger specimens measure about 22 mm. by 12 mm., which is considerably bigger than Kinberg's type. An immature example measures only 6 mm. by 3½ mm.

*Collector's Notes.* Dr. Crossland made the following notes on the living specimens:—"Coiba. Short and stiff and elytra are uniformly coloured. They completely cover the animal, and the feet are invisible but for dense

tufts of fine notopodial chætæ which form a continuous fringe just outside the elytra. The elytra are reticulated honey-comb fashion, but colour is quite uniform."

"In coral, Gorgona Island. Red-brown colour due to body being filled with scarlet eggs, which colour shows through the brown elytra to some extent. Underside of body rose-red. Neuropodial chætæ stiff and dark-coloured; notopodial fine, white, and directed both dorsally and ventrally. Elytra shaped to overlap tile-fashion over the back."

#### Genus CHÆTACANTHUS Seidler.

##### CHÆTACANTHUS MAGNIFICUS (Grube).

*Iphione magnifica* Grube, 1875, p. 51; Seidler, 1924, p. 97.

*Occurrence.* "Coiba Island. Dredging off convict settlement in 5-10 fathoms." "Gorgona Island. Dredging close to shore in 15 fathoms: shell, dead coral, and gravel." Coll. Crossland.

*Remarks.* Two specimens, the larger of which measures 28 mm. by 12 mm. including the feet. The presence of gill-like structures on the feet, the dorsal chætæ which resemble those of *Iphione*, and the elaborate fringing and tuberculation of the elytra are characteristic of this species. This is the species upon which Seidler's genus is founded, and it is its first record outside the West Indies.

*Collector's Notes.* Dr. Crossland made the following note on the living specimen from Gorgona:—"Body showing centrally pinkish elytra, sandy with points on antero-dorsal half and fringes laterally; anterior elytra have small, round, dark dots. Chætæ short and stiff, dark brown in colour."

#### Genus HARMOTHOE Kinberg.

HARMOTHOE HIRSUTA Johnson. Johnson, 1897, pp. 182-183, pl. vi, figs. 27-29; pl. vii, fig. 38; pl. viii, figs. 53, 53 A, 53 B, 53 C: Chamberlin, 1919, pp. 51-54, pl. ii, figs. 2-8; pl. iii, fig. 1.

*Occurrence.* "James Bay, James Island, Galapagos. Shore pools in lava." "Gorgona Island, coral." "Balboa. Rocks and rock-pools, low tide at Panama." "Taboga. From floats at the stage at the end of the hotel piers." Coll. Crossland.

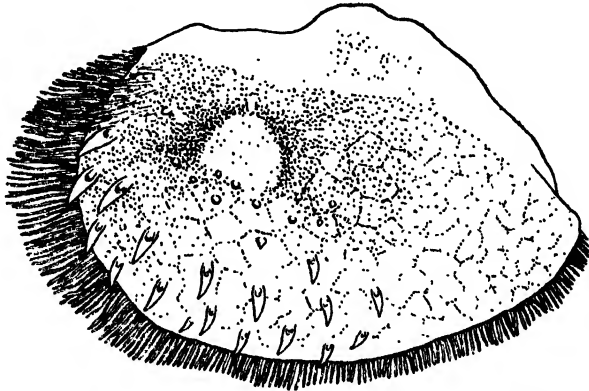
*Remarks.* Seven specimens, the largest of which measures 17 mm. by 7 mm. including the feet. The Panama specimens differ in a number of particulars from Johnson's description. The anterior pair of eyes is situated laterally and not on the top of the prostomium. The tentaculophores and the ventral surface of the prostomium, together with the anterior lip of the mouth, are unpigmented. The division of the elytra into polygonal areas is more extensive and not so much confined to the posterior portion, where the large tubercles are situated (text-fig. 8). Instead of branching into a number of forks or prongs, the large tubercles are simple, curved, and spine-like in

form. The lamination in the ventral chætæ is not continued so far down the shaft as in the typical specimens, and the rows of spines on the dorsal chætæ are more pronounced and stand further out from the shaft. In all other respects these Panama specimens tally with Johnson's description.

Chamberlin (*loc. cit.*) redescribes this species and points out that it is distinguished from the closely-allied *Harmothoe polytricha* Ehlers by the nuchal tubercle behind the prostomium.

*Collector's Notes.* Dr. Crossland made the following note on a living specimen from Taboga:—"The colour on the elytra is in round spots and there are projecting points and fringes to the elytra. Also the long and more slender chætæ project dorsally as well as laterally. Although the coloured processes etc. are more abundant medianly, there is no distinction between coloured and colourless areas of the elytra."

TEXT-FIG. 8.



*Harmothoe hirsuta* Johnson. Elytron showing simple tubercles.  $\times 20$ .

**HARMOTHOE LUNULATA (Delle Chiaje) var. PACIFICA var. nov.**

*Harmothoe lunulata* Fauvel, 1923, p. 70, fig. 26.

*Occurrence.* "James Bay, James Island, Galapagos: 5-6 fathoms, clean sand with several species of weed." Coll. Crossland.—"Taboga: 4-5 fathoms, sand and stone." Coll. Mortensen.

*Description.* Four specimens, the largest of which measures 14 mm. by 2 mm. including the feet. The body is narrow and slender, not tapered at the ends. The prostomium is dark grey in colour and the lower part of the median tentacle is black. The arrangement of the eyes is as in Fauvel's figure. The tentacular cirri are much longer and more slender than those in the figure, and I could detect no bristles involved with them. The elyptrophores are prominent and the elytra have, besides a small black spot over the elyptrophore, an irregular black mark in their hinder part. The patch of small tubercles is sometimes present and sometimes absent.



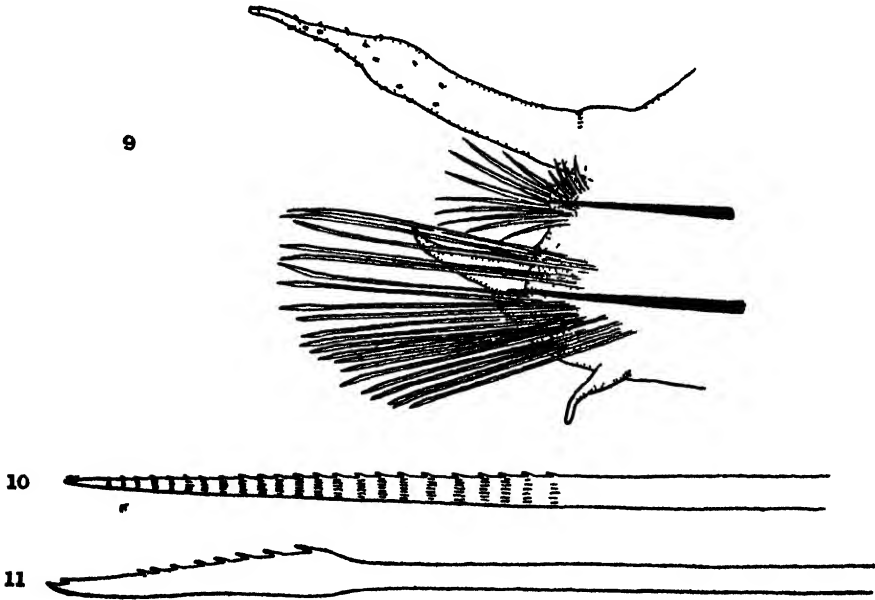
It occurs further back on the elytra than in Fauvel's figure. The feet and bristles correspond closely with those figured by Fauvel for the typical form. This variety differs from the typical form in the greater length of the tentacular cirri, in the absence of chætæ involved with these, and in the slightly different arrangement of the tubercles on the elytra.

*Remarks.* *H. lunulata* is a polymorphic species from the North Atlantic and Mediterranean, and has not hitherto been recorded outside European waters. The occurrence of a variant in the Galapagos is therefore surprising.

*HARMOTHOE BALBOENSIS*, sp. n.

*Occurrence.* "Rocks and rock-pools. Balboa, Panama." One specimen. Coll. Crossland.

TEXT-FIGS. 9-11.



*Harmothoe balboensis*, sp. n.

Fig. 9.—Middle foot.  $\times 65$ .

Fig. 10.—Dorsal chætæ.  $\times 465$ .

Fig. 11.—Ventral chætæ.  $\times 465$ .

*Description.* One specimen, measuring 11 mm. by 3 mm. including the feet. The prostomium is as broad as long, the anterior pair of eyes is quite lateral, and the posterior just in front of the first chætigers. The median tentacle is about twice as long as the prostomium, equal to the tentacular cirri, double the length of the lateral tentacles, and slightly shorter than the

palps. The prostomial peaks are fairly conspicuous, and all the appendages hirsute.

The elytra, having the usual arrangement in the genus, are quite smooth and have the posterior portion coloured black. The dorsal cirri are very long and sparsely hirsute, the ventral short and smooth.

The foot (text-fig. 9) is characterised by its two very prominent acicula and the prolongation of the lip of the neuropodium into a long pointed process.

The dorsal and ventral chætæ (text-figs. 10 and 11) are of about the same thickness, the dorsal being more slender than is usual in *Harmothoe*. They are of the normal pectinated kind. In the superior ventral chætæ the rows of teeth are continued some distance down the shaft. There appears to be in all the ventral chætæ a long, slender, secondary tooth, closely approximating to the apical tooth.

*Remarks.* I had much hesitation in creating a new species for this single specimen, which is not yet fully grown. I am inclined to regard it as a Pacific representative of the Atlantic form *Harmothoe longisetis* (Grube), to which, in the shape of its feet and elytra, it is closely allied. The bristles, however, differ in the two species.

### Genus LEPIDASTHENIA Malmgren.

LEPIDASTHENIA MINIKOIENSIS Potts. Potts, 1910, p. 344.

*Occurrence.* "Galapagos, Indefatigable Island, Conway Bay, shore pools." Coll. Crossland.

Five specimens, the largest measuring 100 mm. by 8 mm. The colour-marking is similar to that of *Lepidasthenia elegans*. The median tentacle is slightly longer than the palps, the lateral tentacles and tentacular cirri being about two-thirds of their length. The prostomial tentaculophores are black.

The absence of any notopodial chætæ, the comparatively large size of the elytra, and the similarity of all ventral chætæ of the same foot refer these examples to Potts's species.

*Collector's Notes.* Dr. Crossland made the following notes on the living specimens:—"Colour principally due to the brown feet, this colour extending as far as the dorsal cirrus, the rest of the foot being nearly colourless. Body with light greenish blotches transversely on either side of the intersegmental line, leaving central part of each segment whitish with specks of clear opaque white. Elytra small and so transparent as to be not readily seen. The first few pairs are rather larger and coloration of the anterior part of the body differs from the above, the brown coloration of the feet beginning at the 11th chætiger. For the first ten segments the body is brown centrally, then green-grey. This is interrupted by whitish marks; a longitudinal mark occupying segments 2-4, then transverse bands which include the feet, after which, a

pair of white longitudinal blotches in each segment which pass into the marks noted above."

Dr. Crossland records several modifications of this colour-pattern observed in different specimens. All the examples lived as commensals with a Terebellid.

### Genus LEPIDAMETRIA Webster.

#### LEPIDAMETRIA VIRENS (Blanchard).

*Polynoe virens* Blanchard, 1849, p. 16, pl. i, fig. 2 (1854).

*Lepidasthenia irregularis* Ehlers, 1901, pp. 54-55, pl. iii, figs. 10-16.

*Occurrence.* "Balboa. Rocks and rock pools, at low tide." "Coiba Island. Dead coral and sand." Coll. Crossland.

*Description.* Thirty-two specimens, the average size of which is about 30 mm. by 4 mm. including the feet. The prostomium is deeply pigmented, and there is a black spot beneath the median tentacle. The first 40 segments are marked by dark transverse bands across the dorsum, darker in the cirriferous segments than in the elytriferous. Further back they give place to single intersegmental bands. In the cirriferous segments the dorsal surface of the foot is splashed with black, and on every foot below the cirrus or elytrifer is a black spot. The single-toothed type of chaeta which occurs in the posterior segments resembles that figured for *Polynoe gigas* Johnson, 1897, pl. viii, fig. 48 B.

The arrangement of the elytra was observed in seven specimens. This is similar in all the examples up to the 35th segment. Posterior to this the elytra occur on the following segments:—

A. 35, 37, 38, 40, 42, 43, 44, 46, 47, 48, 50, 52, 53, 54, 56, 58, 60, 61, 62, 65, 66, 67, 69, 70. In this specimen segment 47 had a cirrus on one side and an elytron on the other.

B. 35, 37, 38, 40, 41, 42, 44, 46, 47, 48, 50, 52, 53, 54, 55, 57, 58, 59, 60, 61, 63, 65, 66, 67. No abnormal segment.

C. 35, 36, 37, 39, 40, 42, 43, 44, 46, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58, 60, 61, 63, 64, 65. Segments 55 and 57 had a cirrus on one side and an elytron on the other.

D. 35, 37, 38, 40, 41, 42, 43, 44, 46, 48, 49, 50, 51, 52, 54, 55, 56, 58, 59, 60, 61, 63, 65, 66, 68. Segments 60, 61, and 66 had both cirrus and elytron.

E. 35, 37, 38, 40, 42, 44, 46, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58, 60, 62, 63, 64, 65, 67, 68, 69, 70. In this specimen the ninth segment had a cirrus on one side and an elytron on the other.

F. 35, 37, 38, 40, 41, 43, 44, 46, 48, 49, 50, 52, 54, 55, 56, 58, 60, 61, 63, 64, 65, 67, 68. No abnormal segment.

G. 35, 37, 38, 40, 42, 43, 44, 46, 48, 49, 50, 52, 54, 55, 56, 58, 60, 61, 62, 63, 64, 65. No abnormal segment.

*Remarks.* Augener (1924, p. 241) discusses this species, and I follow his suggestion in making Ehlers's species a synonym of Blanchard's. Blanchard

gives an excellent coloured figure of the entire animal, and it is this rather than that author's inadequate description that has led me to adopt Augener's suggestion.

This species has many characters in common with *Lepidametria gigas* (Johnson) from California. The feet and the elytra appear to be similar in both species, but the two species differ greatly in size. Johnson's species runs up to 165 mm. in length, while this species is not recorded above 75 mm. long. In this species the elytra continue to the pygidium and in *L. gigas* they do not. Furthermore, in Johnson's species between the 33rd and 49th segments the elytriphorous and cirriferous segments alternate regularly, in *L. virens* they do not.

Dr. Crossland records that the examples from Balbao were found living as commensals in the tubes of "terebellids." In a bottle from that locality among a number of parchment tubes and debris I found, together with examples of this species, several specimens of a small sabellid with two types of hook in the thoracic tori. I believe them to be *Sabella aulacolata* Marenzeller, and presumably they were the commensals to which Dr. Crossland refers.

*Collector's Notes.* Dr. Crossland describes the *L. virens* from Balbao in the living condition as follows:—"The worm is elongated with small blackish elytra, not covering the back. Round colourless spot where the elytron is attached, then black broken by light dashes and specks. Body pinkish with transverse markings of dark grey, one large patch and one narrower of these marks to each segment."

#### Genus HALOSYDNA Kinberg.

HALOSYDNA RETICULATA Johnson, 1897, pp. 170-172, pl. vii, figs. 32, 41, 41 a; pl. viii, figs. 47, 47 a, 47 b.

*Occurrence.* "Taboga Island from floats off the stage at end of Hotel pier." "Tagus Cove, Albemarle, Galapagos." Coll. Crossland.

*Remarks.* Twenty specimens, the larger of which measure about 20 mm. by 5 mm. including the feet. The elytra are pale grey with a light spot over the elytriphore. The first three pairs are provided with a few large tubercles, and in two or three specimens the last four segments have about four large granular tubercles on the outer edge of the scale. All the elytra have a series of small oval tubercles running parallel with the outer margin. There are no fringing papillæ. The ventral bristles are sharply bidentate. There are three examples of *Halosydna* from Tagus Cove, Albemarle, Galapagos; two from fine gravel in pools on the south side of the Cove; and one from a marine garden formed by the shelter of a large overhanging rock. I attribute these very doubtfully to *H. reticulata*. The two from the fine gravel have the elytra mottled with dark grey spots instead of the uniform light grey of the Taboga specimens. The single specimen from the marine garden is an uninterrupted chestnut-brown. The general facies of the

Galapagos specimens is more massive than that of the Taboga *Halosydna*. The elytra are much thicker and are entirely without the larger tubercles. The rows of minute oval tubercles near the outer margin are, however, present. The ventral chætæ are also different, for they are for the most part unidentate. In some bristles I can detect a small spur or rudimentary tooth between the main hook and the rows of frills, but this appears to be absent from most of the chætæ. This may be a form intermediate between *H. reticulata* and *H. brevisetosa*.

The genus *Halosydna* is in great need of revision, for the majority of the species are very ill-defined. Those with 45 segments are clearly separated from those with 37 segments, but within these two groups the species are separated on the presence or absence of fringing papillæ on the elytra, of a secondary tooth on the ventral chætæ, and of various types of tubercle on the scales. In *H. reticulata*, *H. brevisetosa*, and *H. mülleri*, the fringing of the elytra is not a constant character; and experience of other Polynoid genera shows that, in general, little reliance can be placed on small differences in the shape, size, abundance, etc., of the tubercles of the elytra to yield good specific characters.

The presence of the secondary tooth on the ventral bristles seems to be more constant, but the specimens from the Galapagos described above show an intermediate condition. Seidler (1924, p. 110) lists four species—*H. punctulata* (Gr.) and *H. australis* (Kbg.), *H. fusca* (Johs. Müller) and *H. brasiliensis* (Kbg.), all from the east coast of South America; they are insufficiently differentiated. This is equally true of *H. samoensis* (Gr.) from Samoa, *H. marginata* (Gr.) from Callao, *H. mülleri* (Gr.) from Callao, and *H. reticulata* Johnson from Southern California.

*Collector's Notes.* Dr. Crossland made the following notes on the living specimens from Taboga:—"General colour greenish grey, due to elytra; darker anteriorly. Body, where visible, in a few anterior segments white with grey lines transversely, three to each segment, underside white. Outer quarter of each elytron is colourless and transparent, showing the feet. Chætæ all strong, in short straight bunches, no fine dorsal ones. A white spot in each elytron at attachment, and another, irregular, antero-median to this.

"On contraction the middle of back becomes visible through nearly the whole length."

On a second batch of specimens, taken at a different date from the same locality, he writes:—"The second dot on the elytra is only present in some specimens and then only on a few anterior elytra, which are often largely mottled white. There is a dark ring of colour round the spot at the attachment. The back is not exposed at all in life."

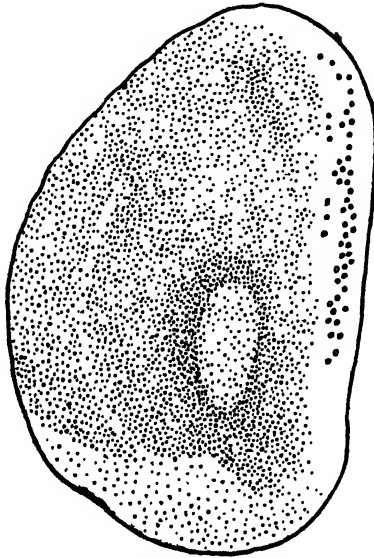
On the single chestnut-brown example from the "marine garden," Albemarle, Galapagos, he made the following note:—

" Beautiful chestnut brown due to elytra, the body and feet being whitish. The outer part of each elytron a much lighter tint and transparent, the two parts being clearly marked off. Opaque whitish-brown spot at the point of attachment of each elytron, oval with a dark brown line round it; otherwise the elytra have a very clear uniform tint, except numbers 2 and 3 on the left side only, which have some darker spots. Dorsal cirri a rather darker brown with white pointed tips."

*HALOSYDNA GALAPAGENSIS*, sp. n.

*Occurrence.* " Tagus Cove, Albemarle, Galapagos. Fine gravel in pools.'  
Coll. Crossland.

TEXT-FIG. 12.



*Halosydna galapagensis*, sp. n. Elytron.  $\times 35$ .

*Description.* One specimen, measuring 15 mm. by 3 mm. including the feet. There are 21 pairs of elytra and 45 segments. The prostomium is broad and the eyes are situated far back, laterally and close to each other. The median tentacle is lost. The palps are short with dark longitudinal markings and end suddenly in a thread-like tip. The lateral tentacles are slightly shorter than the palps and the tentacular cirri are very long, reaching some distance beyond them.

The antero-external portion of the elytra (text-fig. 12) is colourless, the remainder a pale grey. Around the edge of the colourless portion are a few small tubercles.

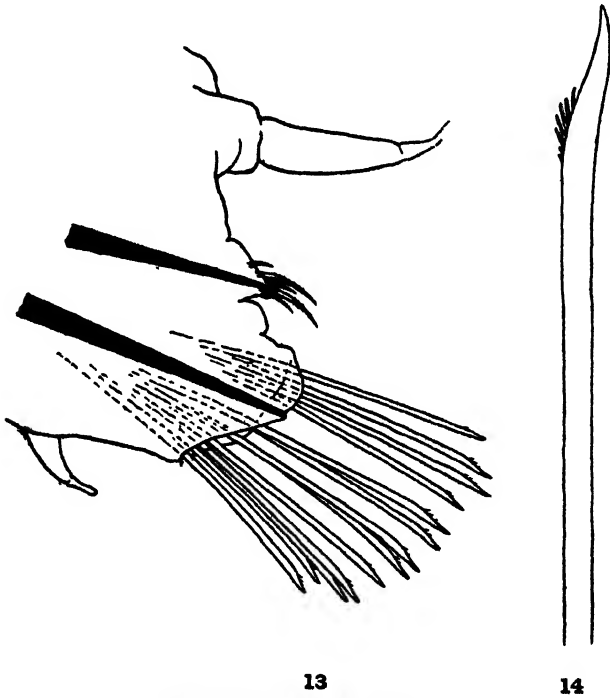
The feet (text-fig. 13) are more biramous in form than is usual in

*Halosydna*. The dorsal cirri are short and do not reach to the end of the bristles; the ventral cirri fall short of the lip of the chætal sac. The dorsal aciculum pushes the surface of the foot into a small rounded lobe, and there is a small bundle of curved strongly-toothed dorsal chætæ.

The neuropodium is roughly triangular in outline with the aciculum thrusting forward into the apex. The ventral chætæ (text-fig. 14) are unidentate with about ten rows of frills.

*Remarks*. This is the only species of *Halosydna* belonging to the group with 21 pairs of elytra which has unidentate ventral bristles. The shape of the foot is unusual for the genus, but in all other respects it is a typical

TEXT-FIGS. 13-14.



*Halosydna galapagensis*, sp. n.

Fig. 13.—Middle foot.  $\times 55$ .

Fig. 14.—Ventral chæta.  $\times 175$ .

*Halosydna*. It appears to be closely related to *Halosydna brasiliensis* Kinberg, which has very similar elytra, but Kinberg's species has bidentate bristles and also, according to his figure, the shape of the foot is different.

#### *HALOSYDNA FUSCOMARMORATA* (Grube).

*Polynoe fuscomarmorata* Grube, 1875, p. 62; Augener, 1906, p. 117, pl. iii, figs. 41-44; Seidler, 1924, pp. 120-122.

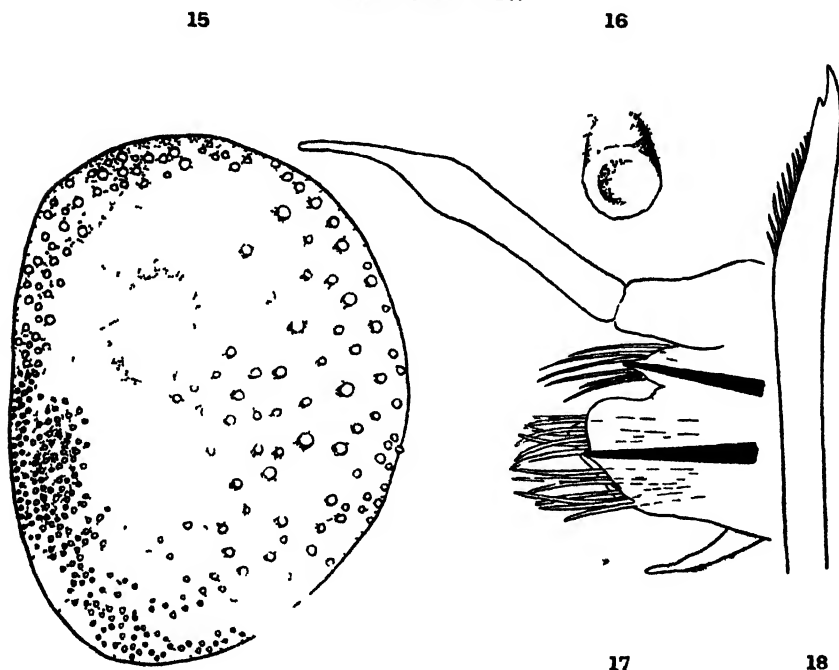
*Occurrence*. "Colon, coral flat near Limon Bay." Coll. Crossland.

*Remarks.* Two specimens, of which the larger measures 25 mm. by 5 mm. including the feet. This species belongs to that group characterized by 18 pairs of elytra, bidentate ventral bristles, and unfringed scales. The elytra are a deep black except for a narrow area between the elyrophore and the outer margin. Augener's description and figures leave little to be added. I can confirm Seidler's statement that in this species the tubercles are not confined to the margin, but spread over the whole surface. *Halosydna leucohyba* (Schmarda) is a closely-allied West Indian form, but the tuberculation on the elytra is much more strongly developed than in Grube's species.

*HALOSYDNA ELEGANS* (?) Kinberg, 1857, p. 18.

*Occurrence.* "Tagus Cove, Albemarle, Galapagos. Fine gravel in pools." Coll. Crossland.

TEXT-FIGS 15-18.



*Halosydna elegans* Kinberg.

Fig. 15.—Elytron.  $\times 35$ .

Fig. 17.—Foot.  $\times 35$ .

Fig. 16.—Large type of papilla.  $\times 165$ .

Fig. 18.—Ventral chaeta.  $\times 200$ .

*Description.* One specimen, measuring 13 mm. by 3 mm. including the feet. The prostomium is of the ordinary *Halosydna* type and the eyes set far back and laterally. The median tentacle and the tentacular cirri are of the same length, about  $\frac{2}{3}$  the length of the palps. The lateral tentacles are slightly shorter than the median. The colour has mostly disappeared from



the specimen, but it can be seen that the elytra, especially in the anterior region, were mottled with some dark pigment, probably grey.

There are 18 pairs of elytra (text-fig. 15), the edges of which are wholly without a fringe. In addition to a large number of small oval tubercles mostly concentrated near the outer wall of the scale, there are many much larger tubercles (text-fig. 16) scattered over the surface with circular flat tops and shaped rather like a vase.

The dorsal ramus of the foot (text-fig. 17) is more developed than is usual in *Halosydna*, and the dorsal chætæ are longer, more slender, and more numerous. In the ventral chætæ (text-fig. 18), which are markedly bidentate, the frills are continued further down the shaft than is usual in the genus.

The dorsal cirri are long, reaching far beyond the tips of the bristles; the ventral are short, their ends scarcely reaching to the end of the chætal sac.

*Remarks.* It is impossible to recognise Kinberg's *H. elegans*, described from the Galapagos, with certainty, for he does not give any figures. He gives 19 as the number of the elytra (possibly more), but this may be a mistake. I suggest that when he describes the elytra as "cellulis magnis ovalibus instructa" he may be referring to the vase-shaped tubercles already described. Were it not for the shape of the larger tubercles I should have attributed this specimen to *H. patagonica* Kinberg. But in that species the tubercles are definitely thorn-like.

### Family **Acetidae**.

#### Genus **EUPANTHALIS** M'Intosh.

*EUPANTHALIS KINBERGI* M'Intosh, 1877, p. 404, pl. lxii, figs. 12-15; Fauvel, 1923, p. 100, fig. 38, i-q.

*Occurrence.* "San José Island, Perlas Islands. 25 fms. Mud and shell." Coll. Mortensen.

*Remarks.* A single fragment, measuring 18 mm. by 6 mm. including the feet. Comparison with an example of this species from Naples revealed no differences of specific value. Ehlers found it in the Gulf of Naples.

#### Genus **PANTHALIS** Kinberg.

*PANTHALIS JOGASIMÆ* Izuka. Izuka, 1912, pp. 68-71, pl. ii, fig. 6; pl. viii, figs. 1-6.

*Occurrence.* "Gorgona Island. 20-30 fms., dredge. Bottom fine sand and shell." Coll. Crossland.

*Description.* Two specimens, both incomplete. The largest has twenty-one chætigers and measures 14 mm. by 10 mm. including the feet. The body is pale brown, and the elytra are chestnut-brown with a lighter edging.

The first foot is modified, markedly biramous, and its dorsal chætæ are fine, slender, slightly curved and faintly hirsute on the convex side. The median ones are stouter with an enlargement towards the apex, as figured by Chamberlin (1919, pl. xii, fig. 1) for *Panthalis panamensis*. The ventral chætæ are finer and more hirsute. In the first few segments the curved serrulate-subspiral type of bristle takes the place of the penicillate kind found in all the median and posterior feet.

More posteriorly the arrangement corresponds to Izuka's description. The glandular threads which Izuka records as being absent from his specimen are present in these. Izuka states that the animal lived in a tube of very fine thread-like substance. This tube it presumably built itself, so that it is puzzling that he should have been unable to find the glandular threads.

*Remarks.* Chamberlin has described a *Panthalis* with two pairs of eyes, *Panthalis panamensis* from Panama. The two species are very much alike, but the penicillate chætæ are different.

*Collector's Notes.* Dr. Crossland made the following notes on the living specimens from Gorgona Island. "Body-colour light purple red, lighter in the larger specimen. Elytra light brown and laterally transparent but the posterior half is opaque chestnut, and this part is fringed with an irregular band of primrose colour. Large stalked eyes are prominent as in No. 5 (*Polyodontes oculæa*). Tubes exactly like No. 5, but perhaps less gelatinous. In the larger specimen the five anterior pairs of elytra are speckled with spots of yellow and the yellow border is not distinct as it is in the uniformly coloured ones posteriorly."

### Genus POLYODONTES Renier.

POLYODONTES MORTENSENI, sp. n.

*Occurrence.* "Taboga, Panama. Mud and sand." "Melones, Panama. 3-5 fms." Coll. Mortensen.

*Description.* Three specimens, two incomplete.

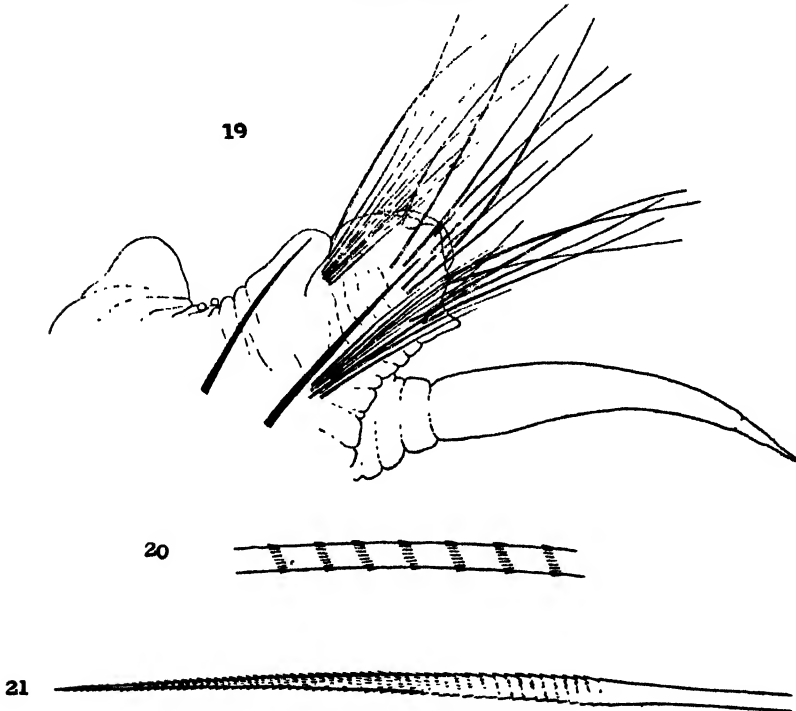
The complete specimen measures 145 mm. by 11 mm. including the feet. In spirit the dorsum is a reddish brown and the ventral surface a pale yellow. The prostomium is silver with fawn-coloured appendages dotted with black spots, and it is continued forward as two deeply pigmented ommatophores ending in crystalline lenses. The posterior pair of eyes is situated behind the ommatophores at about the level of the insertion of the median tentacle which reaches forward a little beyond the ommatophores. The lateral tentacles cannot be seen from above, as they are hidden by the ommatophores. All the buccal appendages are stout, subulate and of much the same length, except the palps, which are long and carry rows of small papillæ.

The arrangement of the elytra is as usual in the genus. They are reddish brown, quite smooth, and with the external edge reflected to form a pouch. The first three or four pairs are marked with a number of black dots similar

to those on the buccal appendages. There are a few fine capillary chætæ involved with the peristomium.

The 1st foot is clearly biramous (text-fig. 19) with divergent chætal bundles. The dorsal ramus which lies in front of the ventral consists of a rounded lobe with an aciculum lying above a bundle of fine capillary chætæ with distinctly serrated edges (text-fig. 20). The ventral ramus is a simple flattened two-lipped sac containing the ventral capillary chætæ, the lowest of which are

TEXT-FIGS. 19-21.



*Polydortes mortenseni*, sp. n.

Fig. 19.—First foot.  $\times 25$ .

Fig. 20.—Section of dorsal chæta of 1st foot.  $\times 500$ .

Fig. 21.—Ventral chæta of 1st foot.  $\times 125$ .

backwardly curved and have rows of pectinæ (text-fig. 21). On the dorsal surface of the foot below the elyrophore are two delicate globular processes re-sembling stylodes.

The dorsal ramus very rapidly becomes flattened and closely applied to the anterior face of the ventral chæta sac, as in Fauvel's (1919, p. 340) descriptions of *P. melanonotus*, and its chætæ are accordingly very difficult to distinguish from those of the ventral ramus. I was unable to find with certainty the segment at which the dorsal chætæ cease. They seem to persist for about thirty segments.

At the 7th foot the ventral ramus consists of two pockets, an upper and anterior with a single anterior lip, and a lower and more posterior two-lipped pocket. Posteriorly these two pockets are fused into one. In the second foot the ventral ramus contains two kinds of bristles, a few stout aristate bristles in which the terminal plume is almost always lost and a large ventral sheaf of the type known as "serrato-subspiral." By the 5th foot the ventral ramus has in addition two capillary chætæ with hairy ends, similar to those figured by Fauvel (*loc. cit.*) for *P. melanonotus* (pl. xvii, fig. 73). By the 7th these bristles have become modified into penicillate bristles, whose axis passes beyond the brush of hairs and ends in a fine

TEXT-FIGS. 22-24.

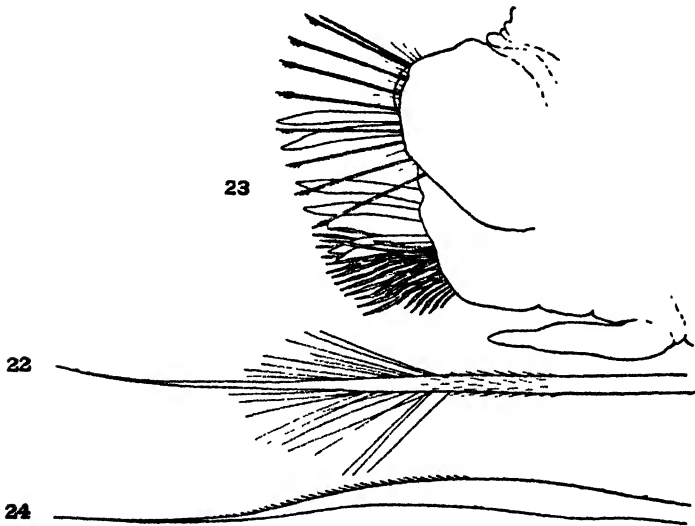
*Polydortes mortenseni*, sp. n.

Fig. 22.—Penicillate chæta from 10th foot.  $\times 180$ .

Fig. 23.—10th foot.  $\times 25$ .

Fig. 24.—Modified penicillate chæta from 60th foot.  $\times 180$ .

point (text-figs. 22 and 23). By the 60th foot they are once more modified and become long, slender, lanceolate bristles with a hirsute end (text-fig. 24). In the most posterior segments of the body there are only two kinds of bristle, the aristate and the serrato-subspiral.

On the 1st foot there is a large ventral cirrus; on the remaining feet the ventral cirri are very small. The dorsal cirri are thick and short, scarcely reaching the end of the chætæ sac.

The branchiæ begin on the 7th foot. For the first half of the body they consist of a number of small digitiform processes. Posteriorly to this they appear as two large globular transparent sacs, and in the final segments

of the body these sacs become joined into a single large branchial organ in the dorsal surface of the foot.

The spinning glands begin on the eighth foot and the nephridial papillæ on the ninth.

*Remarks.* This species is very close to *Polyodontes melanotus* Grube. It differs, however, in the structure of the first foot. In Grube's species the dorsal ramus has a distinct digitiform process which in this species is a small rounded lobe and the bract is absent from the ramus. Furthermore, in this species the dorsal chætæ do not become larger and more lanceolate from before backwards.

I am inclined to regard *P. bicolor* Grube, described by Augener (1918, p. 119), and *P. melanotus*, as the same species. Chamberlin's *Panthalis panamensis* is presumably a true *Panthalis* without branchiæ. The only distinction between this genus and *Polyodontes* appears to be the presence or absence of branchiæ.

#### POLYDONTES OCULEA (Treadwell).

*Panthalis oculea* Treadwell, 1902, p. 188, text-figs. 14-18.

*Occurrence.* "Taboga. Mud and Sand." "Taboga, about 10 fms., mud" (Coll. Mortensen). "Taboga, dredging, 1-2 fms. "Dead broken coral." "Balboa, rocks and rock-pools." "Low tide at Panama." "Trinidad, Port of Spain Roadstead, 4-5 fms., thin mud." "Colon. Trawling in Limon Bay, 5 fms., thin mud." (Coll. Crossland.)

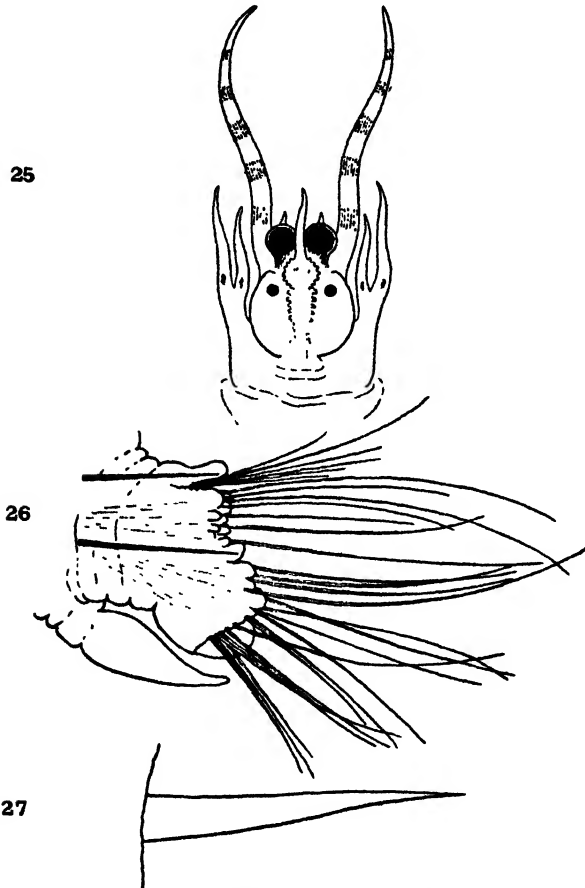
*Description.* Twenty specimens, of which the largest measures 52 mm. by 8 mm. including the feet. Body-colour in spirit a pale yellow with dark transverse striation across the back in the anterior segments. The prostomium (text-fig. 25) is conspicuous by its large black ommatophores ending in pale crystalline lenses, which appear to vary considerably in size in the different specimens. Behind the ommatophores and between the two prostomial eye-spots arises the short median tentacle, the base of which joins on to a minute folded ridge like a rudimentary caruncle running the whole length of the prostomium. The lateral tentacles are normally hidden from above by the ommatophores, but in a few examples they project a short distance beyond the ommatophores. The palps are large, reaching to the 8th chætiger when laid along the back, and are flecked with dark pigment throughout their length. On the proboscis on either side of the large median papilla dorsally and ventrally there are six small papillæ which have at their base severally a small pigment spot. The jaws resemble those described for *P. maxillosus*.

The first pair of elytra meet above the prostomium; the rest leave a considerable area of the back uncovered until towards the end of the body, when they again approach each other. They are very conspicuous owing to the black bordering which marks both their inner and posterior edges, as in

*P. maxillosus*; and on their outer side their edge is turned over and back to form pouches. The elytra have no papillæ.

The 1st foot (text-fig. 26) is modified; the dorsal ramus is digitiform, supported by an aciculum and carrying a number of papillæ (? stylodes).

TEXT-FIGS. 25-27.



*Polyodontes oculus* (Treadwell)

Fig. 25.—Head.  $\times 25$ .

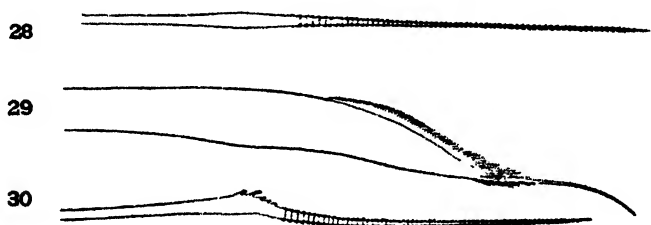
Fig. 26.—First foot.  $\times 35$ .

Fig. 27.—Median chaeta from 6th foot.  $\times 200$ .

The ventral ramus is on the posterior surface of its upper division cut up into a number of finger-shaped processes, and the lower division bears an oval lamella (bract). The most dorsal chaetæ are very fine and delicately hirsute. Ventral to these are a number of much stouter and larger chaetæ with a spear-head enlargement below the tip. They are faintly spinose

above the enlargement and have a curved apex free from spines. By the 6th foot (text-fig. 27) the dorsal ramus assumes a more lip-like shape and the spear-headed chætæ are larger and more spinous. By the 17th foot the dorsal chætæ have almost disappeared and the dorsal ramus takes the form of a lip, up against the anterior face of the ventral ramus. Seen from before backwards the chætæ are divided into three groups. Most anteriorly rising from the lip of the dorsal ramus there are a few fine hirsute dorsal chætæ; below and behind the dorsal ramus is an upper pocket of superior ventral chætæ of two sorts, spear-headed chætæ and chætæ of a more slender form with regularly spaced bands of spinelets (text-figs. 28). Posterior to and slightly below these is a pocket with two vertical lips from which emerge a few aristate chætæ (text-fig. 29). No penicillate chætæ are to be seen. Below the aristate chætæ is a large bundle of the type of bristle known

TEXT-FIGS. 28-30.



*Polydonte ocula* (Treadwell).

Fig. 28.—Spinous superior ventral chætæ from 17th foot.  $\times 225$

Fig. 29.—Aristate chætæ from 17th foot.  $\times 225$ .

Fig. 30.—Ventral chætæ from 17th foot.  $\times 225$ .

as serrulate-subspiral (text-fig. 30). By the 50th foot the two pockets of the ventral ramus have been fused into one, the dorsal chætæ have disappeared, and the feet are more prominent.

In the anterior segments the dorsal cirri are small and digitiform. More posteriorly they increase in size and look like flaccid bags of skin.

The branchiæ begin on about the 20th chætiger and consist of a number of small bladder-like structures on the dorsal surface of the foot. One is usually to be seen closely applied to the posterior face of the elythrofore.

The thread glands begin at the 9th chætiger.

*Remarks.* The marked modification of the 1st foot and the presence of gills refer this form to *Polydonte*, and it is noteworthy that no penicillate chætæ are present. Treadwell's specimens appear to have had lateral tentacles projecting far beyond the ommatophores. This is not the case in my examples, but I remarked some variation in the length of these

organs. That which Treadwell describes as the dorsal ramus of the foot is the upper part of the ventral ramus. It is remarkable that examples of this form were found on both sides of the Panama Canal.

*Collector's Notes.* Dr. Crossland made the following notes on the living specimens:—"Port of Spain Roadstead, Trinidad. The species is unmistakably recognized by the black-brown borders to the middle and posterior edges of the elytra. Inside this, a band of bright opaque primrose-yellow; the rest of the elytra colourless and transparent. Slender body and feet very light flesh-colour, but brown posteriorly in some sexually immature (?) specimens. Body pointed in front, rounded behind. Head prominent, two long palps with white dots and a pair of stalked eyes which in life could be protruded from under the first elytra almost like those of *Strombus* from its shell. Prostomium and fore-body and first two pairs of elytra with white spots of irregular shape like the yellow ones which form the bands on the elytra. The elytra do not meet in the middle line; in the larger specimen a wide bare space along the back. The tubes are irregular masses of slimy mud and mucus rather pointed at each end. Also common in Limon Bay, at the Atlantic end of the Panama Canal.

"Taboga Island, Panama Bay. Anterior elytral borders dark brown rather than black, posterior elytra with black borders, but unmistakably the same species as those obtained months ago on the other side of the Isthmus of Panama."

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Coral Reefs of Tahiti, Moorea, and Rarotonga. By CYRIL CROSSLAND, M.A.,  
D.Sc., F.Z.S. (Communicated by Professor J. STANLEY GARDINER,  
F.R.S., F.L.S.)

(PLATES 35-39 and 14 Text-figures.)

[Read 1st March, 1928.]

## I. TAHITI.

The structure of the island itself, as Professor Davis has so rightly insisted the essential preliminary to a discussion of its reefs, has been described in the *Journal of the 'Royal Geographical Society'*; an abstract of my findings will suffice here.

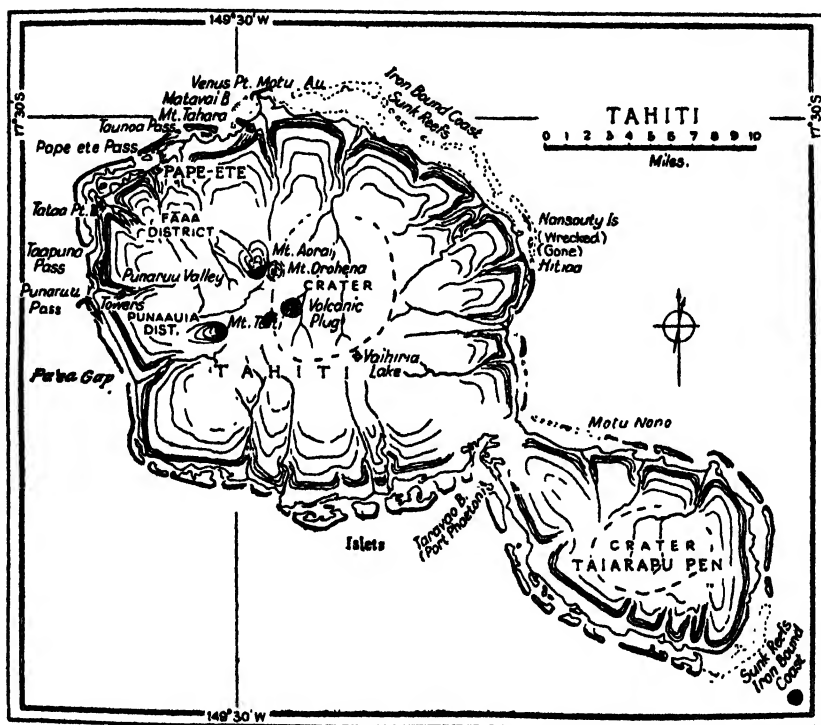
Tahiti is a pair of lava cones, each with a single vent, deeply dissected, it is true, but recent in comparison to the other islands of the Society Group. It shows no clear evidence of movement with respect to the ocean level except that very recent positive movement which has left traces all over the Pacific, and which, in Tahiti, is shown by shelves about six feet above the sea at the bases of basaltic cliffs, by old beach deposits, and, as we shall see, by certain features of the reefs. There are small flats at the valley mouths, but these by themselves do not necessarily indicate subsidence, and, in any case, I shall show that the barrier form of the reef is independent of change of level. There is no raised coral rock forming land surfaces anywhere in the island, but coral rock is to be seen in the beds of streams, its elevation being so trifling that elsewhere it is either buried beneath alluvium, or, if exposed to the sea, cut down to the level of the present-day reefs.

The island is cliffed all round, but having been protected by reefs for so long these cliffs have been degraded into steep slopes. No outlying volcanic rocks project through the coral at any point. The islets on the reefs are all of purely coral formation, thrown up under present conditions of sea-level; they are neither the "volcanic outliers" of Agassiz nor formed of basaltic sand, and they have no special relation to the underlying detrital platform. The alluvial and coral flat which surrounds the island, and which is its whole economic and social value, is founded upon the coral reef. Its extension over it is now stopped, and even reversed, erosion being evident round the whole circumference of the island in spite of the quantities of alluvium brought down by the streams and the growth of coral in the lagoons. Its disappearance is, geologically speaking, an event of the near future, and with it will go the human value of the island. This simple structure and uneventful geological history adds much to the value of the

exploration of these reefs, since we have here the simplest case, free from the complications of older islands and continental shores, with their long histories and complicated changes, in which a whole series of successive reefs may have combined to give the present resultant formations.

The regularity of the reefs encircling these islands is their most striking characteristic. In all the islands except Tahiti the girdle is complete, broken only by narrow passes, and in the latter case, where the barrier is absent from the surface, soundings complete the ring by revealing it only

TEXT-FIG. 1.



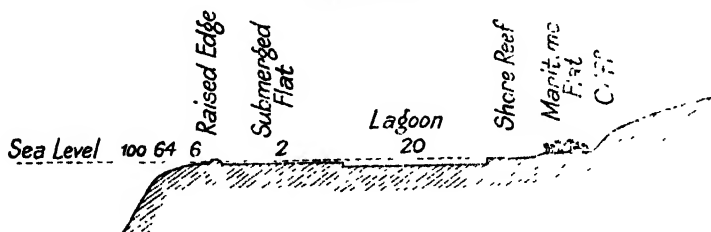
The old cliffs are shown diagrammatically on an exaggerated scale. Reef-edge double line, sunk reef dotted, shore-reefs and submerged flats single lines. For details see large-scale charts of text-figs. 3, 6, and 7. (By permission of the Editor of 'Discovery'.)

about five fathoms below. Any large-scale chart shows that the reef may consist of the following parts:—(1) Fringing reefs along the shore; (2) a lagoon of considerable depth, either as a broad stretch of water or a mere passage between; (3) lagoon reefs; and (4) beyond the lagoon the "Barrier Reef," consisting of a submerged flat, under a fathom or less of water, and the surface ridge upon which the ocean waves spend their force.

The surface of the shore-reef, close in shore, is of broken coral branches with sand and mud; there is not, as a rule, the hard rock surface which is

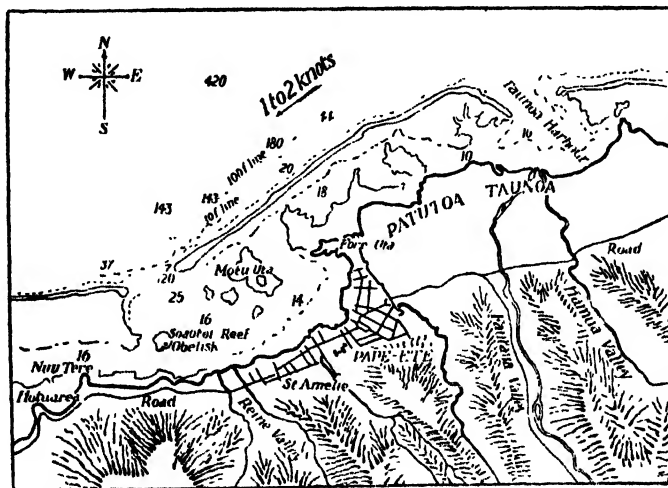
found in the corresponding position on the reefs of East Africa or the Red Sea, to mention only the examples familiar to the writer. It is generally remarkable how near shore corals live. Wading in water, ankle to knee deep, only a few yards out, one finds inconspicuous incrustations of *Favia*, etc., on the dead branches of other corals and a finely branched cream-coloured *Pocillopora* (*P. damicornis*) with numerous crab "gulls," *Parona*,

**TEXT-FIG. 2.**



Section through the reefs of Fana south of Tataa Point. Soundings in metres. Lagoon depths twice the true scale. Height of marine flat and palms grossly exaggerated to make them visible. (By permission of the Editor of 'Discovery')

TEXT-FIG. 3.



Papeete Harbour to Taunoa, showing passes and irregular lagoons.

"stag-horn" *Acropora* flourishing along with other forms in spite of occasional floods of red mud. Towards the edge an abundant fauna appears, many other species of *Acropora* (*Madrepora*), the delicate "bouquet" forms often conspicuous, while some peculiar forms of *Montipora* add to the beauty of the scene with patches of bright violet. The smooth massive species of *Porites* are here small and not common—we shall see them later on the submerged flat—their place being taken by a species—*P. sociorum* Bernard = *P. convexa* Dana, the surface of which is covered with little vertical

branchlets. Usually this species is in cake-like slabs a foot or two across by a few inches thick, but in certain places it grows into great domes and cylinders up to twelve feet in both directions, forming boulders in the coral wall of the lagoon edge.

This coral growth along the edge of the shore-reefs slopes precipitously to the deep water of the lagoon, the living corals occupying the upper fathom or two, the rest being a talus of sand and coral branches.

The lagoon may be lake-like or a mere channel; in either case its bottom and sides are formed of dead coral and coral sand, the rarity of mud from the land being surprising evidence of the strength of the currents. Broad or narrow, the other side of the lagoon is completely different from the shoreward, and rises as a pure sand slope without coral. On the shoreward reefs, too, the water over the corals is but an inch or two, between them perhaps a foot at low tide, but on the far side the reef is six feet or more under water. At first the bottom of this submerged flat is of bare coral sand, but further out level rock surfaces appear, and big blocks of *Porites* coral, four to six feet in diameter, approach or reach the surface. Many of these are dead, partially or entirely, and form a support for branching species of *Acropora* and *Pocillopora*, which cannot live on the sand-swept bottom. Others are decayed away, some to mere shells, while others bear no resemblance to coral colonies at first sight, and have been taken to be blocks of reef-rock torn from the ocean slopes and thrown over the crest of the reef by the waves. As we shall see later, there are no blocks on the outer slope which could be detached, and more careful inspection of these rocks shows their origin from the decay of coral masses, which grew where they now stand. The water now shoals gradually, to a depth of two or three feet near the raised edge, sand becomes less abundant, and, just within the raised edge of the barrier, over which ocean water is poured into the lagoon by every wave, a bed of branched corals, species of *Acropora* and *Pocillopora*, may grow directly on the bottom.

In times of heavy surf this is as far as the canoe can be taken without being swamped by the waves raised by the inpouring water, and landing on the edge is impossible (Pl. 35. fig. 1); but when the surf is low we can walk for miles between most of the deep passes, on the broad and nearly level rock surface, having a general breadth of 30 to 50 yards, shown in Pl. 36. figs. 3 & 4). The edge of this surface-reef often falls abruptly to the lagoon into about three feet of water between the colonies of growing coral, where these are present; it is followed by a very gentle upward slope, to a height of one or two feet, sometimes a little more, above low-water level, from which point is a steeper descent to the ocean. The lagoonward slope is covered with brown weed (*Sargassum* with some *Turbinaria*), from which it is referred to as the *Sargassum* flat. This abundance of brown weed, occupying a broad band all round the island, is remarkable, as such

weeds are generally rare in the tropics, and here, in crossing the lagoon, we saw none but a few plants of *Turbinaria* about the edges of the lagoon-reefs, or possibly none at all. Under the weed the rock is painted a bright red with encrusting *Lithothamnionæ*\*, which are visible, but of a duller colour, on the bare crest and outer slope. These are roughened by irregular growth, and the latter also by projecting knobs of the harder underlying rock (see the two photographs on Pl. 36). Though superficially similar throughout its length, the composition of the surface of the reef-edge varies completely with its height above the water. These differences of height are, as a rule, so small and gradual that attention may be drawn to them first by changes in the flora, the most conspicuous of which is the occurrence of a grey "coralline" weed on the higher parts. On attempting to dig into the crest of such a reef one meets with hard impenetrable rock everywhere, which, like the lagoonward slope, is merely painted over with *lithothamnionia*. Where the reef-edge is lower conditions are entirely different, the whole surface being soft and composed of living corals and *Lithothamnionæ*, solid *Millepora*†, and other reef-forming organisms. The corals are all of the special forms adapted to this surf habitat, the corymbose, "bouquet-like" species of *Acropora* taking the form of solid stemless slabs, even losing their upright branchlets in some cases; the *Lithothamnionæ* are predominant to the eye, giving a general dull pink colour to the reef, so that in appearance it does not differ much from the higher parts we have just visited, but it is really secondary to the corals, as any part prised up is found to owe its major bulk to coral. The two sets of organisms live in a kind of balance, and, from comparison with other parts of the reef, one concludes that neither alone could form the crestal ridge, which is so essential a feature of the barrier edge.

On prising up pieces of this combination hollows are frequently found underneath, and the roofs of these are rich in life, including three especially beautiful forms, the coral *Dendrophyllia* (which nowhere grows exposed to the light), with its large flower-like orange or scarlet polyps, the beautiful violet Hydrocoralline *Distichopora*, and the Foraminifer *Carpenteria*, in branching spicule-pointed growths an inch or so thick, while *Homotrema* forms numerous bright red spots half an inch across. Though the whole surface is an amazing wealth of vigorous life, yet the total number of species to be collected is not large.

The softness of this material is not due to rottenness of the coral, and boring organisms are not as abundant as would be expected. The most

\* Principally *Porolithon onkodes*. Setchell, W. A., "Phytogeographical Notes on Tahiti," Univ. Calif. Publications, 1926, xii, No. 27.

† This, presumably, is the 'orange-coloured nullipore' of Agassiz's description; also the surface is not "rotten," as Agassiz states, but soft through its being made of loosely-cemented growing organisms.

abundant worm, for instance, is the harmless *Eunice antennata*, instead of the great borer, *E. siciliensis*, and, in comparison with the Red Sea, all kinds of boring organisms are rare.

**NEGROHEADS.**—Of projecting knobs of rocks, the remnants of the old reef once at a higher level, such as are described by Dana in the Tmautotus, there are none here. On the outer barrier edge, *pace* Agassiz, there are no upthrown rocks whatever, and the only abrupt break in its level is due to faulting. There are two sets of pieces of the reef-edge which have been thrown up, but both are within the mouths of passes, at Atine and Hotumataia, on the west and south coast, the former (shown in Pl. 37. fig. 8) is the only large mass, being about eight feet high. It is easy to see that these are parts of the overhanging shelves of the outer parts of the passes, that

TEXT-FIG. 4.

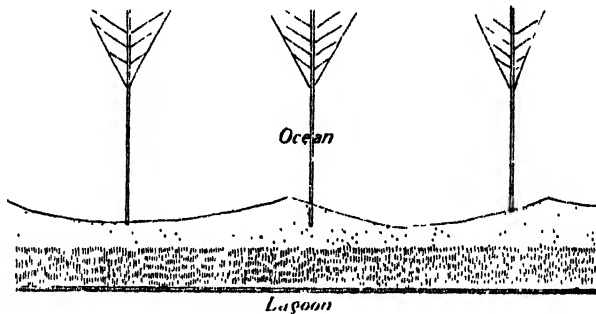


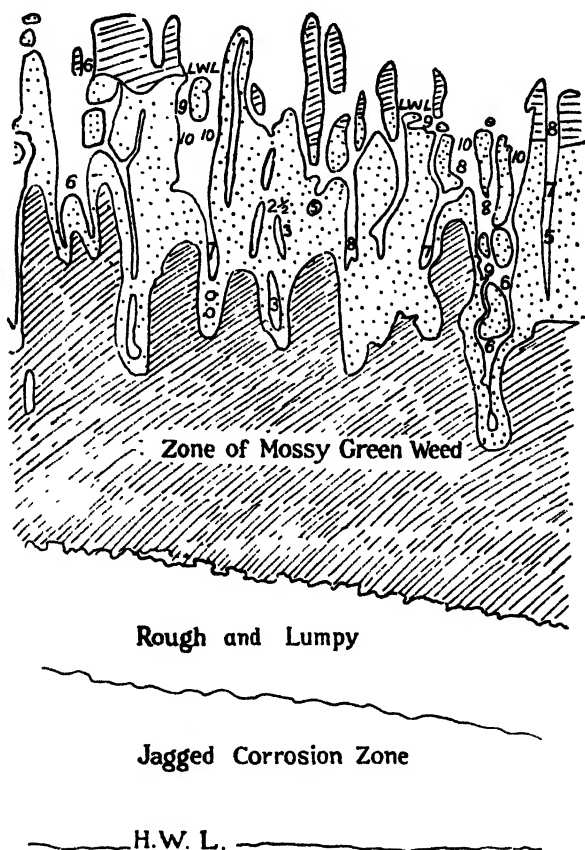
Diagram of the reef-edge as seen at moment of maximum retreat of a wave. Dotted, crest and outer slope of knobby lithothamnion and corals. Dashes, the *Sargassum* area. Shaded, step to the lagoon water (where the edge is high). Three trenches are shown leading to the beginnings of ravines.

at Atine still bearing the surf-modified coral characteristic of this situation. This is in marked contrast to the Atoll of Napuka, described by me in Trans. Rôy. Soc. Edinb. lv, (2) 1927, where upthrown blocks abound.

On shore-reefs exposed to surf large boulders are common in places; these are practically all *Porites* colonies or basaltic boulders from the cliffs, reef-rock being rare. I know of two masses of reef-rock only, one near the mouth of the Fautaua river, the other on the shore reef of the east side of the peninsula of Taravao; smaller pieces may have escaped my notice. Additions to these upthrown blocks of the shore-reefs are rare; nearly all are blackened and worn in a way that, there is evidence to show, can result from an exposure of not less than a hundred years. It seems strange that the long overhangs of certain shore-reefs and passes are not frequently broken off and thrown on to the reef, and it seems probable that they are usually too fragile to last long after being so violently handled. The hard rock of the shelf of the Napuka reef is quite another thing; much of that in

Tahiti would scarcely support its own weight were the water withdrawn. Besides *Porites*, great slabs of corymbose *Acropora* are sometimes thrown on to the reef, one in Matavai Bay being seven feet long. It is scarcely possible to imagine living corals, or recently formed coral rock, with its light specific gravity, being able to stand on the reef-edge, exposed to the

TEXT-FIG. 5.



The reef-edge of Funafuti, showing outgrowing tongues of *Lithothamnionæ*. These when dry at low tide are dotted, below this level cross-hatched. The figures show depths of included channels in feet. (From the Report to the Royal Society, 1904.)

tremendous rush of water from the surf. Old rock, solidified by recrystallisation, can do so, as on the reef-edge of Zanzibar\*. Where the reef is masked by an islet, as on certain of other islands of the Society Group, conditions are different, waves rise and fall, but do not send so overwhelming a current across the reef.

\* Crossland C., "The Coral Reef of Zanzibar," Proc. Camb. Phil. Soc. xi, 1902.



The outer slope is remarkably regular, there are no outlying masses of coral, nor projections seaward from the reef-edge of any kind. In watching the breakers, in order to see as much as possible of the outer slope during the retreat of the largest waves, a trench-like depression may appear for a moment, its continuation below water being clearly seen by refraction in the next advancing wave. The effect these have upon the way the wave breaks being noted they are found to be quite numerous in all the reefs, and under favourable conditions are easily seen from the reef-edge; but, of course, are best examined from a canoe by a water-glass. Near their heads they are practically always about two feet wide by three or four deep, nearly straight with vertical parallel sides. It is to be emphasised that these are trenches cut into an otherwise regular slope, they are not spaces left between outgrowing tongues of reef, and there is no comparison at all between them and the peculiar outgrowth of, for instance, the Funafuti reef. To make clear the important difference I copy here the outline of a portion of the Funafuti reef-edge, given in the Report to the Royal Society, alongside a diagrammatic sketch of the Tahitian trenches. (Figs. 4 and 5.)

The slope for the upper five fathoms or so is at a slighter angle than between 5 and 12 fathoms, and is, in fact, the part which is normally influenced by the surf. Coral growth is abundant everywhere, but the fauna is peculiar in the predominance of rather small specimens of corymbose *Acropora*, which are placed in a peculiarly formal manner, being set out at intervals of two or three feet apart on the smooth bare bottom. Thick-branched *Pocillopora* is also common, and other genera are present but relatively inconspicuous. Massive *Astreans* do not exist, except a *Favia*, which attains the size of oranges. A greater contrast to the crowded corals, of every form, which cover the slopes of the Red Sea reefs, could hardly be possible, unless, as in Zanzibar, coral growth had ceased altogether. Below 5 fathoms corals are more abundant, and may almost cover the bottom, but at 10 or 12 fathoms they die out quite suddenly, and for the next 7 fathoms, *i.e.*, as deep as is visible under the best possible conditions, the slope is of barren rock and sand, the sand appearing at this depth for the first time\*.

\* I cannot reconcile what I have clearly seen, on repeated occasions, with the statements of my predecessors. I can make nothing of the account given by Agassiz, who places the limit of abundant coral growth at 4 to 6 fathoms, the rest of the slope to 18 fathoms being covered with broken and dead coral. He did not see the trenches, the most remarkable feature of the reef. The 'Challenger' account is also based on too cursory an examination; it appears that structures seen just outside the passes were taken as typical of the whole length of reef. It also states that living coral covers the bottom to a depth of 35 fathoms; but "coral" is a technical term on charts for any white deposit, or mud, found near coral reefs. The relative abundance of corals, not merely their presence or absence, can be estimated only by actual sight of the bottom, and as in 1926 I could make out all details at 17 fathoms and see dimly to 20 (I have seen to 25 on one occasion) there is no doubt of the statement made above.

## THE REEF IS NO LONGER GROWING SEAWARD.

In the reefs east of Papeete Pass these trenches run down to a depth of 10 fathoms, and are throughout clean-cut, perfectly bare of any growth or of sand or coral débris, evidently being under a strong scour. The whole reef is being swept clean continually, and even after weeks of calm weather there is no sign of accumulation. Sand has been seen in small quantities in another locality, an "exception which proves the rule" for the rest of the reefs examined. Through the lower parts of their courses the trenches run at the foot of ravines with sloping sides, and it is to be noted specially that the sides of these ravines are just as well covered with corals as are the open slopes outside them. The existence of these ravines proves that the effects of the eroding scour are not confined to the trenches, as if the growth on the sides of the ravines were sufficient to cause any advance, their walls would become vertical and finally close up, the trenches being probably reopened elsewhere. Also, for the same reason, it is proved that neither is the general surface of the reef any longer extending seawards. The conclusive proof is found in the presence here and there in the trenches of collections of boulders, large and small, many of which are of basaltic rock. These are well rounded, and by their motion in the trench under wave-action may have some effect in their cutting; but it is certain that if they are moved to and fro their resultant motion, under the downward drag of the surf, is downwards, out of sight. It is not possible to regard them as parts of the foundation rock of the reef; they are the same in every way as the stones we find embedded in, and lying upon, the shore-reefs and the submerged flat respectively—*i. e.*, they are stones which have been carried on to the reef by floods, and across it by tidal and wave currents, at a time when the lagoon channel did not exist and the reef-surface was continuous from shore to ocean. Again, now that the supply of these stones is cut off, and those which are exposed upon the steep slope cannot remain long before disappearing into the depths, fresh supplies must be continually laid bare by the erosion of the coral rock in which they are embedded, as, if the reef were growing ever so slowly, all must have been buried in coral long ago\*.

\* Prof. W. M. Davis points out that the absence of slope is a difficulty in the way of the conveyance of these stones across the reef. I have seen the process in operation on the peculiar and quite modern reef of Ilana Hevané in the Marquesas, where the motive force is entirely marine, stones wandering out *along* the reef from a cliff against which the reef abuts at one end. Prof. W. A. Setchell points out that fishermen use stones to sink their lines in deep water outside the reef, detaching the stones by jerking a slip-knot when the bait reaches the bottom. The outer slope of the reef must be littered with such stones, but (1) none of them are in such shallow water as 5-20 fathoms; (2) most of these I refer to are much larger than those used by fishermen. I have myself suggested that the stones might be floated over a lagoon entangled in the roots of trees ('Nature,' cxx, 1927, p. 618), but reject this because the stones are always rounded, which would not invariably be the case in stones uprooted by trees, especially at a time when the present shore-flats were not formed. Mr. Graham, Sudan Government Geologist, points out that rounded basaltic concretions would lose all trace of their outer decaying shells under very little rolling and become indistinguishable from river-worn boulders.

Another proof of this discovery, that a reef carrying good supplies of growing coral and other reef-forming organisms may not be growing seaward but actually going back follows from the fact that much of the reef-edge is an erosion flat, the relic of the old reef formed when the ocean level was higher. The reef has not grown broader since the level fell. A particularly clear case is given by the raised coral rock of the Moorea reefs to be described later. The contours of the outer slopes off Papeete were sounded by the 'Challenger,' and show a nearly vertical cliff about 600 feet deep, along the face of the reef, its summit being 45 fathoms, or 270 feet, below the surface. The similar feature of the Funafuti reef was examined with especial care by Prof. Edgeworth David, whose description is remarkably complete when one considers the extreme difficulty of dredging, etc., upon such an area; but it is difficult to agree with Prof. David's conclusion, and that of the naturalists with him, that, by most ingenious ways, the face of the cliff is slowly but continuously growing outwards. It is hardly possible to regard these cliffs as anything but the result of submarine erosion, and as evidence that at these levels erosion is going on even more rapidly than above, perhaps owing to the absence of organic protection, combined with a higher solubility of limestone under the increased pressure. The occurrence of this cliff, in the face of so many reefs, seems to the writer a fact of great significance, possibly indicating that reefs all over the world were formed under conditions differing from those which now rule.

The history of the reef-crest seems to have been as follows. At the time of the fall of the ocean-level great lengths of reef were left above the sea at a height of six feet, corresponding with that of the basaltic shore-shelves of the north-east coast and the raised coral rock in Moorea. There is now no raised coral in Tahiti, but the higher portions of the reef-edge, already described, are erosion flats, well above the level at which they could have been formed under present conditions and composed of very hard old rock. The cutting down of coral rock is rapid above sea-level, witness the wide flats of eroded coral on every coast of raised reefs, but, at the level at which it receives protection from the growth of stony organisms, the process is relatively slow. Where the level has, however, been further reduced, the growth of coral, plus lithothamnium, forms a new surface. Even this breaks down near the ends of the reefs at the passes, where corals alone fail to make a continuous surface, the colonies being separated by areas of loose sand. South of Papeete Pass, for example, and along the north coast of Moorea, where the reef-edge is at its lowest, the crest being hardly above low-tide, is an intermediate condition, in which the corals are cemented together on the seaward slope within which is a band of coral, almost, or quite, free from lithothamnium, and consequently unable to form a continuous surface.

There is one place where the change of level is abrupt, a mile south of the

Punaruu gap, on the west coast, where a length of about a hundred yards of the reef is seen from a distance to be two feet at least higher than that to north and south of it, ending in a distinct drop to the lower level at its south end. This is accompanied by marked evidence of local faulting in the reef, a phenomenon which has occurred almost everywhere, and may have been of great importance. Other raised platforms, due to the erosion of emerged reefs, are found, but less frequently, in certain shore-reefs and in the maritime flat where exposed by rivers, but all are inconspicuous and stand at most two or three feet above sea-level.

#### THE WESTERN REEFS. OUTER SLOPES.

It seemed next to be important to discover whether, in other parts of the island, the reefs are still growing outwards, though the chart's showing a remarkable uniformity in the outline of the reef-edge makes this seem unlikely, and indicates that the variations in its breadth are probably due to differences in the platform of erosion and deposition upon which it is founded.

Owing to the impossibility of getting a seaworthy boat, and the weather in 1926 being so often too rough for work outside the reefs in a canoe, examination of the outer slopes southwards was possible only as far as the Punaruu Gap on the west coast and a small portion of the reefs off Tautira on the north-east side of Tairapu.

The outer slopes are here also being eroded, but at a slower rate. In the northern part of this section the trenches are deeply cut and very conspicuous in calms, when they appear like black ribbons on the light upper slope just outside the reef-crest, but differ from those of the Papeete reef in generally ending abruptly at the lower edge of this upper slope. They contain the usual collections of stones, many of which are certainly lava. Where they continue through the next zone they are quite shallow, and contain stones and sand at their bottoms. Farther south, from near the N.W. angle to near Taapuna Pass, is a section of reef, the only one I have seen in the whole circuit of the island, in which trenches are altogether absent (I have seen much more of the reefs by walking along the edge than from the outside by boat). At the same time a scoring of the bottom is visible everywhere, either as lines of flat rock at right angles to the reef-edge separated by grooves a foot or two deep or, at the lowest level visible, by streakiness in the arrangement of the sand and débris. The corals are the same as on the northern reefs, but the proportion of *Pocillopora* to *Acropora* is higher, and the species of the former with thinner branches (? *P. bulbosa*) is common, but, in July 1926, every colony of this species, and of this species only, was white, i. e., had died within a week or two. The quantity of living coral present was variable; sometimes the upper slope was bare, in other cases coral was as abundant above the 3-fathom line as below. Sand and

débris are seen at times, a clear distinction from the reef east of Papeete Pass, and the general impression gained is that both growth and the mechanical destruction of the corals proceed more rapidly here, the result being visible in a rougher surface. This coast is exposed to a much heavier surf than is that of the north-west, and thus meets the reef at an angle, to which I attribute the absence or shallowness of trenches in the deeper water.

Towards Taapuna Pass the slope becomes abnormally steep, and the usual more gentle slope in the breakers narrow. The sudden change in the soundings on the large-scale French Admiralty chart just north of Taapuna Pass represents a steep talus slope, due to breakdown of the reef, and in the inward bend of the reef-edge immediately north of the pass the upper slope is nearly absent, the depth given being found as near the reef as the surf would allow the boat to go, *i. e.*, the crest of the wave next to that breaking on the reef. Just north of the Punaruu Gap the slope, between 5 fathoms and the surf, is very thickly covered with corals, but below that the drop is precipitous, soundings of 10–15–25 fathoms being found a few strokes of the paddle apart, and farther north, when the canoe was on the next wave to that breaking, the sounding is 10 fathoms. Corals are here always abundant (though not so much so as on the top of the precipice near the gap, which is quite exceptional)—about half the bottom is actually covered with living corals, not including encrusting *Montipora* and lithothamnium.

These precipitous portions of the outer slope suggest areas of specially rapid erosion, not unexpected just north of the Punaruu and Taapuna Passes, from which sand etc. is swept northwards, and which, indeed, is evident in the outline of the reef north of the gap. Another striking case, for which this supposition explanation does not apply, is to be seen on the reef opposite Papawa, east of Papeete, where soundings of 66 fathoms close to the edge attracted my attention. I found here that below  $2\frac{1}{2}$  fathoms the reef is undercut into a projecting shelf; immediately beneath this is a depth of 12 fathoms, with an almost vertical descent to the full 66 fathoms. As soundings alone cannot indicate undercutting, cases may be common at depths at which shelves are not visible. These cases of special local erosion will be referred to again when describing the Passes.

In other cases a specially wide reef-trench may exist; one opposite Faaa Church is just sufficient to make the break of the waves less violent, and permit small canoes, very skilfully handled, to pass the reef from the lagoon for deep-water fishing.

REEFS EAST OF PAPEETE show signs of general decay to some extent more marked than those described in the general account of average conditions. As stated above, the heads of the trenches are rarely seen, being just exposed at the maximum retreat of the waves; but on the eastern of these reefs, and that off Point Venus, they sometimes penetrate into the crest and drain parts of the *Sargassum* area, where they end in shallow funnel-shaped depressions.

This incursion is checked by the growth of coral, which can be seen occupying the upper ends of trenches at Point Venus. The Admiralty chart shows that the shallower slope outside the crest is broader than usual, and possibly there has been a movement of the crest over the reef lagoonwards (the line of crosses in the chart does not mean projecting rocks or "negro heads," as one might expect, but merely shallow water). Off Motu Au, a little east of the point, this feature is still more developed, there being a considerable area covered by breakers.

The *Sargassum* flat is narrow on the Papawa section, and ends lagoonwards in a little cliff through most of its length, not only near its end, as on the Papeete section towards Taunooa. Outside, the corals, slopes, trenches, and their ravines all seem much as elsewhere, but there is a good deal of the Fucoid weed *Turbinaria* on the outer slope, even as deep as 10 fathoms, and it is often more abundant than all the corals; in other places a soft red weed abounds, and though most of the upper slope appears to be covered with encrusting lithothamnion, much of it is grey and dead-looking. Below 5 fathoms most of the bottom is covered with corals as usual, but, also as usual, the colonies are not crowded together, even in specially rich areas. In the calmest weather it is interesting to see that the weed sways to and fro with the waves as deep as 5 fathoms, if not deeper. The outward swing is longer than the upward, showing that, even in water so shallow as this, the resultant motion is downwards.

It is in the lagoons that this section of the reefs shows its greatest peculiarities, they appearing to have recently come under a very strong erosion, the evidences for which will be given in their proper section.

**THE SUNK REEFS.**—These are indicated by dotted lines on the chart (text-fig. 1), to which the reader is referred for their distribution, and he will note how regularly they fit into the girdle which surrounds the island.

On account of the strong predisposition to believe that all coral reefs are still growing, it has been taken for granted by former visitors that these reefs are young and in process of growing to the surface, or that they owe their underwater position to local subsidence; a glance at the chart, even without another at the reefs themselves, disposes of the third theory which has been published, that they are parts of the original platform upon which the other reefs have been founded. Commander Wilkes and MM. Clerc and Benaze\* made accurate measurements from marks erected on the shore with a view to finding later the rate at which the reefs are growing upwards, and it was left to Agassiz to find that the portion of the sunk reefs considered, Dolphin Bank, just west of Point Venus, is not a growing reef at all. There is reason to criticize Agassiz's description of the bank, but none for his conclusion, and it is to be hoped that Wilkes's stone will be preserved, not only

\* Dana, 'Corals and Coral Islands,' 1875, p. 215.

for determination of the rate of recession of this bank—which will be a much slower process than normal growth would be—but as a relic of historic interest.

It has been stated in the paper read to the Royal Geographical Society that the maritime flat and shore-reefs all round the north-east quadrant of the island are but remnants, left after heavy erosion of the coast, and that their extent corresponds with the amount of shelter they receive from the more or less imperfect barrier. It is clear that the inhabited flat was of far greater extent once, *i. e.*, at a time when the shore-reefs, as well as the beaches, were protected by a barrier at the surface. In Matavai Bay the same thing is seen on a smaller scale, where the remaining flat is surely being destroyed, and the old line of sea-cliffs, some day, not geologically remote, will again be exposed to the surf. These considerations are enough to prove that the sunk reefs are below water through the destruction of their upper levels, and not because they are too young to have reached the surface. It remains to be seen how far the condition of the coral and other growths upon them correspond with this deduction.

The portions of the sunk reefs which I have examined are, for the reason already given, smaller than I wished. They are (1) the sunken tongue of reef which extends eastwards from the end of the Papawa Barrier ; (2) the western half of the next section, as far as opposite Arue ; (3) Dolphin Bank ; (4) the shallow flats about Motu Au and the sunk reef eastwards as far as Maha Honu Pass. As all the banks seen are alike, the deduction drawn from the few days spent upon them may be taken as safe. Not only in form, but in the species of coral and their distribution, they significantly resemble the familiar Papeete-Papawa barrier. In all cases coral is abundant, as usual from 10 fathoms up to 5, above which it becomes sparse, though the same species are "planted out" up to the top, where the reef rises above 5 fathoms. As a rule, 5 fathoms is the average depth over these reefs, with occasional rises above it, and much of those of Matavai Bay are deeper ; but it is more than a coincidence that this level is that below which coral growth becomes more abundant on the reefs which reach the surface. It is evident that the same cause which thins the growth of coral above this level, *viz.*, wave-motion and the consequent rasp of sand over the bottom, has also cut down the reefs above that level, protection being reduced just where it is most needed. This is also the reason why the most abundant of the corals are the stalked *Acroporas*, in which the mass is raised above the scour, the general importance of which will be emphasized in a later paper on coral ecology. One difference between sunk reefs and those at the surface is that the waves are able to throw quantities of coral over them, so that the landward slope may be a talus of coral branches.

To summarize this section : the reefs of the west and north coasts fall into gradations of decay. All are going back over their whole outer surface, but

their summits remain at sea-level as far as Papawa. Though with variations in structure showing stages in reduction, the crest itself shows no sign of being broken through until the eastern section is reached, in which also the outer slope shows special barrenness in places. Finally, further east, with the exception of the reef off Point Venus, the upper parts of the reefs have been lost, with consequent loss of the flat land along the shore.

### THE LAGOONS AND PASSES.

To quote the 'Challenger' Report: "According to Mr. Murray the reefs were built from shore seawards, and the lagoons were formed and are still forming by the removal of the inner and dead portions—by the solvent action of the sea." After fifty years the conclusion arrived at by this eminent man has been definitely proved, but the words "solvent action" must be used in the broadest sense, to include every form of degradation, and even so marine erosion does not seem to account for the depth the lagoons attain.

Let us first consider the submerged flat, which everywhere forms a band within the raised edge. This is very clearly marked off from the deeper part of the lagoon as a distinct structure, almost uniform all round the island. Although mainly a surface of coral rock, the landward edge is buried in sand, which is being poured over into the deeper lagoon, and only exceptionally does the rock appear in this slope, in the eastern lagoons which we shall consider later. The rest of the surface is sprinkled with coral branches and coarse sand, with insignificant growths of encrusting corals etc. on the former, until near the outer edge, where, as noted, corals other than *Porites* may grow. The excavation of this submerged flat is of a generally uniform breadth, so that, if the reef beyond the lagoon-channel is abnormally wide, excavation will not reach the lagoon and flats remain at water-level on the seaward side of the lagoon.

The origin of this sand and débris is, of course, from the upper part of the outer slope of the reef and from growth on the flat itself. The quantities produced are small: trifling heaps of coral, newly arrived from the outer slope, may be found here and there at the base of the step to the lagoon, and rarely, under special conditions, the travel of the sand is visible as little collections under the lee sides of *Porites* blocks. The current from the surf to the lagoon is easily seen on days when the waves are high, and is strikingly demonstrated in the view from the higher parts of the road in Faa after a flood, when the deep lagoon and shore-reefs are hidden under red mud, while the submerged flat remains green under the clear ocean water, the line between the two being clear-cut. Between the emerald-green of the shore and the blue-black of the ocean, these two ribbons of colour, red and light green, with the white line of the surf, make a picture as vivid as it is illustrative. This current is too strong to allow any permanent accumulation on



the submerged flat, which is clearly one of erosion, and the basaltic stones frequently found upon its surface are those remaining from the destruction of reef-rock six to ten feet thick. Accumulation in the lagoon-channels is not as rapid as might be expected. The longest channel of all, from Papeete Harbour to Taapuna Pass, has been explored by dredging. Seeing the red floods which fill the lagoons after rain (or perhaps one should say "cover the surface"), it is surprising to find the bottom covered throughout with a clean, fairly coarse coral sand, free from mud and containing only 12 per cent. by bulk of black particles of basalt. The grains are angular and have therefore not travelled from any distance. Red mud is deposited abundantly at the heads of the little bays and on the inner shore-reefs, but it seems as though, once it reaches the deep channel, it is all carried out to sea.

It is still more surprising to find no accumulation of mud in the deeper parts of Papeete Harbour, the depth of which is so much greater than that of its Pass to the ocean (see diagram, note, and chart no. 3 on pp. 579 and 601). The bottom, in the western and deeper half, is smooth, with some nodules of Lithothamnionæ covering dead corals and shells, generally rotten and hollow. There is not much weed, *Halimeda* being brought up only once in any quantity, and living coral is represented by tiny incrustations and a triangular Fungiid. In the lagoon there is a thin coating of the marine phanerogam *Halophila* over the sand and scattered plants of *Udotea*; as is usual in coral lagoons there is but little life, a few common echinoderms were practically all that was obtained.

Probably this lagoon is filling from both sides, but the rate is not to be measured by that at which the various materials are poured in, but is the balance of deposition over removal. Whether in any of the Tahitian lagoons this balance is considerable, and whether any of them are likely to be filled in completely, I cannot say. There are other lagoons around the island where, in spite of these sources of filling material, excavation is certainly going on, and, in those of the east coast, this has produced deep and wide basins. In Moorea, on the other hand, where coral-growth is much more active in the lagoons, there is every sign that filling-in has been considerable.

Currents in the lagoon are generally feeble, as there is so small a tide; but if a fisherman can be persuaded to do anything so apparently useless as to take one out when the surf is really high on the barrier, pouring great floods of water over it into the lagoon, especially if at the same time there has been heavy rain, the scene is unrecognisable. The peaceful beauty of the lagoon's usual state is replaced by swirling currents of turbid water, in which the grey coral sand from the bottom is easily recognised; the barrier edge is unapproachable from the rush of water from it to the lagoon. There are now visible ample forces of erosion to account for that observed, and to be described, but these occasions are not common; but for short intervals

the conditions are as peaceful, in fact, as the descriptions of the romantic writers, and the contrast, for instance, with the Red Sea, is very great.

The little cliff on the lagoonward side of the raised edge of the reef shows that its erosion is going on from this side also, through most of its length, though only to a maximum depth of a fathom, generally two or three feet.

The evidences of lagoon erosion are most striking in the Papeete-Papawa area. All the lagoon- and shore-reefs here, through the greater part of their circumferences, drop off sheer into deep water, almost directly into 10 fathoms or more. The edge takes the remarkable form of a shallow broad shelf, overhanging for six or even ten feet, a structure quite without precedent in the author's experience. Though coral grows abundantly above the shelf, little or none is found upon its edge, or upon the fallen pieces which occur below it in places, except on those shoals which are near the Taunoa Pass; on those near the Papeete Pass corals extend a little way down the slopes when there are slopes, but not in any quantity.

There are two ways in which these queer shelves might be made—by the outgrowth of coral, which is confined to so peculiarly narrow a band of the surface-water, or by the undercutting of the sides of the passages by the silt-laden currents. It is clear that the vertical bare rocks below the shelves are the result of erosion, even without the positive proof afforded by the occasional presence of volcanic pebbles and waterworn stones embedded in their vertical walls. Coral is not always present on the tops of the shelves, which, if only a foot or two below the surface, are as barren as the side walls.

Similar shelves are to be seen along the shore-reefs opposite passes, and on those exposed to surf in, for instance, Matavai Bay, and in these cases there is considerable growth of coral and lithothamnium upon them. Attention was given to these cases to determine whether growth, restricted to the upper foot or two, or erosion beneath this level had the most to do with their formation. Growth in the past, that is to say, for there is rarely any growth of coral on the *edge* of the shelf, even when it is abundant on the top. The examination of the east end of the Faaa passage, where it opens out into Papeete Harbour, shows the change from the ordinary reef form, viz., a little irregular wall of growing coral with a talus of debris below it, to the very well-marked shelves of the western shores of the harbour. The conclusion was drawn that growth alone produces shelves of trivial size, if any, and in this case solidification of the surface rock by lithothamnium has made the shelves even more striking than they are in the Taunoa passage, where lithothamnium do not occur in any appreciable quantity.

The reefs east of Papeete are again unique in my experience in being thickly covered with corals over their whole areas. This does not result in making a continuous rock surface, one reason for which is the absence of lithothamnium in any quantity, but chiefly it is that the same cause which enables the corals to grow with this surprising vigour prevents their forming

new rock at water-level, viz., the strong currents of this passage which carry away the material as fast as the corals grow. Where there is a gap in the shelved edge of the reefs the sand can be seen pouring down.

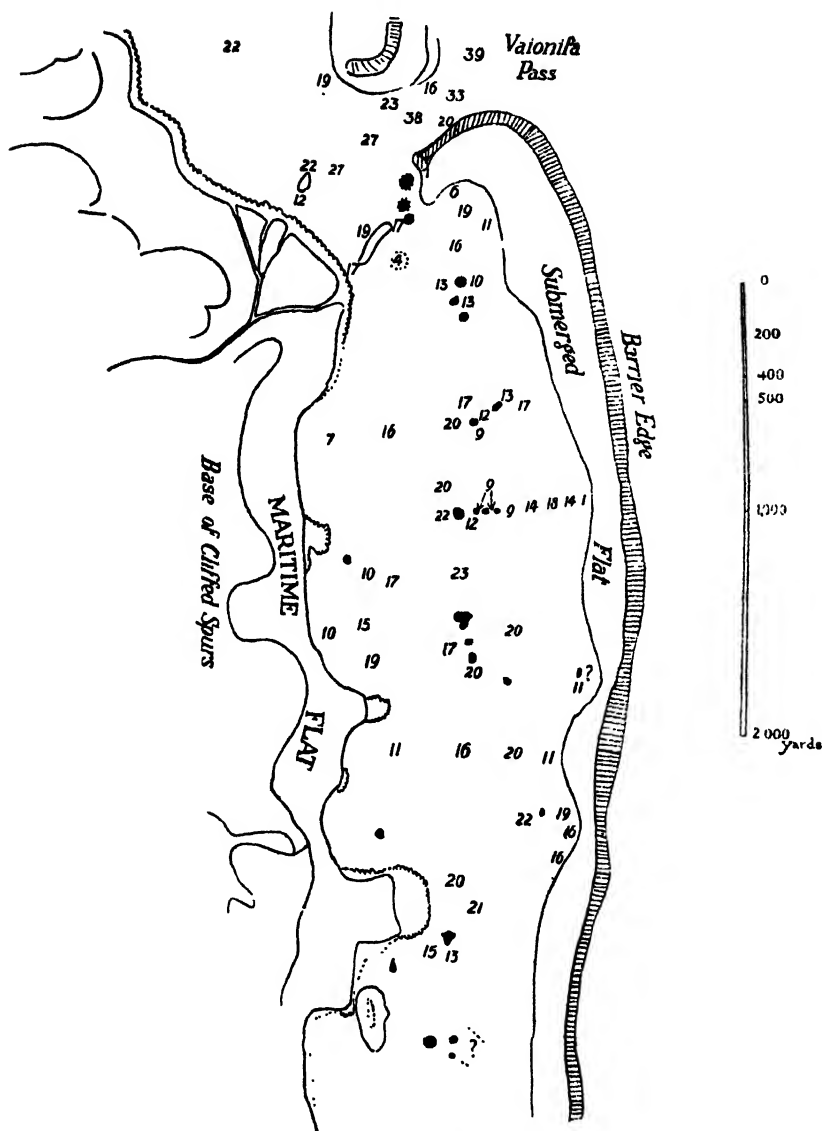
We thus see that, both within and without, these eastern reefs are undergoing abnormally rapid degradation; they are on the way to the condition of the submerged banks of Matavai Bay.

Particular attention is paid to the distribution of these shelved lagoon-reefs. They are found invariably at the sides of the passes, both deep and shallow, right round the island, and along the shore-reefs opposite the passes, where they are kept extended by the growth of *Lithothamnionæ*, which occurs in quantity only where surf reaches the reef, as already described for the west side of Papeete Harbour. Otherwise, throughout the lagoons of the west and south coast, shore-reefs of normal form are the rule, whereas all remnants of shore-reefs of Matavai Bay, and the north and north-east coasts, are deeply undercut. It is clear that the shelved reefs of the Taunoa Passage are simply a stage towards the latter condition; they are in process of breaking down and finally disappearing.

The wide deep lagoons of the southern part of the east coast and the eastern part of Tiarapu with their narrow barrier reefs are remarkable enough on the chart (text-figs. 1 & 6), and I found that the contrast with those elsewhere is more striking still when actually upon them. Here, again, shelved rocks are frequent everywhere and are found *even on portions of the edge of the submerged flat*, on the seaward side of the lagoon. This is unprecedented in any other part of the island, and shows that here, not only is erosion more active than anywhere else, but that the supply of sand from this narrow submerged flat and the shallow part of the slope of the reef outside is far from sufficient to balance it, even on this side of the lagoon. One is forced to believe that conditions here were once analogous to those elsewhere, when coral growth was more active, and that great quantities of sand and coral rock have been removed by erosion within the lagoons, which owe their wide-open character largely, if not entirely, to this action.

The shore-reefs are narrow, but generally of normal form, but shelves occur at Taone and the neighbourhood. The lagoon-reefs are the most interesting feature, having been reduced to their last remnants, groups of pillar-like rocks rising to or near the surface quite abruptly from the blue-black water, as shown in text-fig. 6. They are invariably shelved, and coral growth is either confined to their surfaces or absent altogether. In some cases they seem to have been originally portions of the submerged flat, and in one case a number of rather angularly rounded volcanic stones, 6 to 9 inches in longer diameter were seen, some lying loose, others embedded in the coral rock. (Stones were also seen on the submerged flat, but may have been all of coral, as I had no diver.) The eastern shoals are the more completely dead, their shelves being about 2 fathoms under water with very little coral,

TEXT-FIG. 6.



A lagoon of the east coast of Tairarapu. Like all east coast lagoons it is deep and open, both shore-reefs and submerged flat being narrow, while other lagoon-reefs are reduced. In this case there are twenty-four of these reduced pillar-like shoals, represented on the chart by black dots. In some cases these rise sheer from the bottom of the lagoon, in others from small areas of about half the general depth.

Soundings in fathoms, translated from the large-scale chart of the French Admiralty.

and in some of the smallest shoals farther south the whole surface is  $\frac{1}{2}$  to 1 fathom below the water. Some of these shoals are extremely small, only between 20 and 40 feet across.

The only possible conclusion to be drawn from these pillar rocks is that the lagoon is being excavated to its bottom, on the outer or barrier side especially; while on the shoreward side both the narrowness of the shore flat and reefs show that the quantity of growing coral here suffices only to hold the shore line stationary. The evidence of shore erosion is clear, as it usually is in Tahiti, indicating a lessening of reef protection, and the building up of the shores for their preservation, which Captain Cook noted, still exists in places. On the other hand, there are supplies of coral debris from the shore-reefs, from certain of the pillar shoals, on some of which coral is growing, and the generally sandy slopes from the submerged flat; but one must always keep in mind the fact that in all coral areas deposition and removal are in process together, and the result is the balance of one over the other. As we have seen, there is formation of reef material in apparent plenty on the outer slopes, but that does not alter the fact that there is no permanent addition. Whatever may have been the first origin of these deep and open eastern lagoons, there seems no doubt that they owe their present form to the excavation of an originally more or less continuous mass of coral.

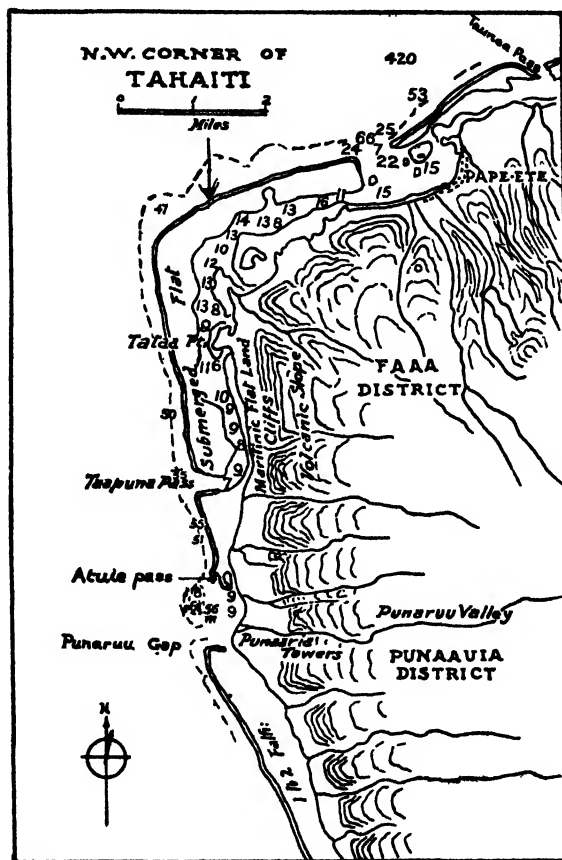
The barrier edge itself is low, so that quite considerable waves cross the lagoon, more directly corresponding with those from the ocean than do lagoon waves where the edge is higher. It is rarely possible to walk upon that to the N.W. of Tautira, and from the absence of an upthrow after a wave has broken, one sees that there is no steep-faced crest all along this reef, as is the case at the southern point examined. Southwards to Vaionifa Pass I walked for some distance on the edge, which, like that off Tautira Peninsula, is flat, so that it remains ankle deep in water between waves; it is without any conspicuous growth of Porolithon, but is covered with "mossy" weeds and coralline. A kilometre or less beyond the pass the usual crest of Lithothamnionæ appears, with very little coral admixed, and the reef-edge then narrows still further *by loss of the inner flat*. There is no lower flat formed by recent coral growth anywhere, and the water pours over the inner side into water a fathom deep. Trenches were seen everywhere by refraction in the rising waves, but were not at all conspicuous on the slope laid bare by a wave's retreat, as they are, for instance, off Point Venus.

N.B. On the Admiralty chart the reef-edge of this side of the island is differently drawn from that of the west. As is seen from the above, this is no more than the difference between the work of two draughtsmen.

The west coast is as complete a contrast as possible. In the north is a comparatively narrow but deep channel, which turns abruptly seawards and ends definitely in the Taapuna Pass. South of this there is no channel or lagoon deeper than the usual 1-2 fathoms of the submerged flat; the whole

lagoon is a sandy expanse dotted with small beds of coral and big colonies of *Porites*, all, as usual, more abundant on the seaward side. This arrangement continues to near the south-west corner of the island, interrupted by the gaps (rather than passes) of Punaruu and Pa'ea. At the south-west corner Maraa Pass begins abruptly the big lagoons of the south coast.

TEXT-FIG. 7.



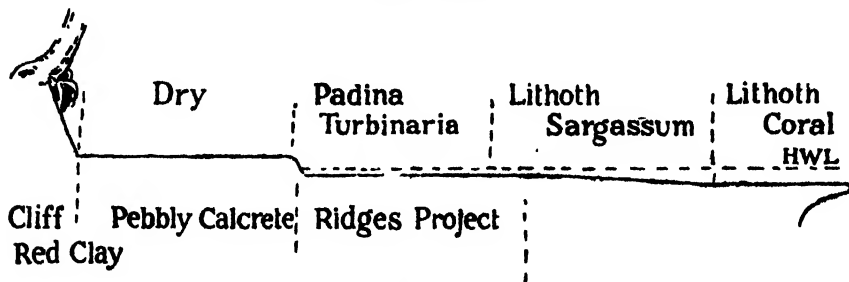
The North-West Corner of Tahiti.

The reef is of the barrier type as far south as Taapuna, after which it is fringing. The varying distance of the 100-metre line (54.7 fathoms) from the reef-edge is noteworthy.

**ORIGIN OF THE LAGOONS.**—That this contrast between the lagoons of the windward and lee sides of the island is connected with the impact of winds and current on the east coast is borne out by comparison with the adjacent island of Moorea, in which, though the state of development is so different, the deepest and most continuous lagoons are also on the east side. That marine excavation accounts for all is not, however, true, as a consideration

of the west coast shows, for here the lagoons are shoaling. A deep channel exists still, while the middle section of the same coast, exposed to exactly the same conditions of marine action and coral growth, is without it. Current erosion has here resulted in the formation of an equivalent of the submerged flat, and nothing more; at least the beginning of a channel from the southern reefs would be expected, but there is no trace of one comparable in any way with that from the north at Taapuna either here or the Punaruu or Pa'ea gaps. The abrupt right-angled turn of this channel, with similar turns elsewhere, strongly suggests that the first origin of the lagoons was as deep cracks, due to earth-movements, which have been altered, and especially widened, by marine erosion of their sides, into the present lagoons. It is with diffidence that local earth-movements are suggested, as it savours of a resort to a *deus ex machina*; but the evidence all points to the first rudiments having been deep and comparatively narrow cracks, such as would be produced in a continuous reef by a slipping downwards and outwards on its

TEXT-FIG. 8.



The western calcrete reef of Arue. Diagrammatic section, from cliff with undermined tree to undercut edge with lithothamnium and corals.

loose alluvial foundations. (This may have occurred during the period of sinking sea-level, which, by leaving a proportion of the reef above the support of the water, added to the pressure on its foundations.) Two systems of cracks would thus be opened, annular, which became the lagoons, and radial, which are now enlarged to form the deep passes.

Evidence of minor faulting in these two directions is to be seen in so many places that it may be taken as having occurred in all the reefs. The evidence consists in the occurrence of ridges standing above the general surface, the result of cracks which have been filled in by a more resistant material, and therefore now stand out, the original rock having been planed down. In some cases the filling material is hardened by inclusion of basaltic sand or pebbles; in the seaward reefs such inclusions are not visible under a lens.

The most striking case is to be seen on the western of the three little shore-reefs of Matavai Bay, this and the eastern being peculiar in that the

landward parts are of a higher level, just above high-water mark, and black and rough like raised coral, for which I took them on my first view from a distance (Pl. 37. fig. 6). On approaching I found that this is not the case, but that the colour is due to an admixture of basaltic pebbles with coral, which makes a resistant sort of concrete; it is probable that it was formed above sea-level of mixed material in the flat, but has now been exposed by the advance of the sea, and its seaward border cut down to water-level, leaving knobs and ridges rising to the older level, as shown in fig. 6 on Pl. 37. These are clearly the material which filled the cracks in the original mass, in places they are so regular and continuous as to hold up a series of regular squared pools, as explained by the diagram. [This

TEXT-FIG. 9.

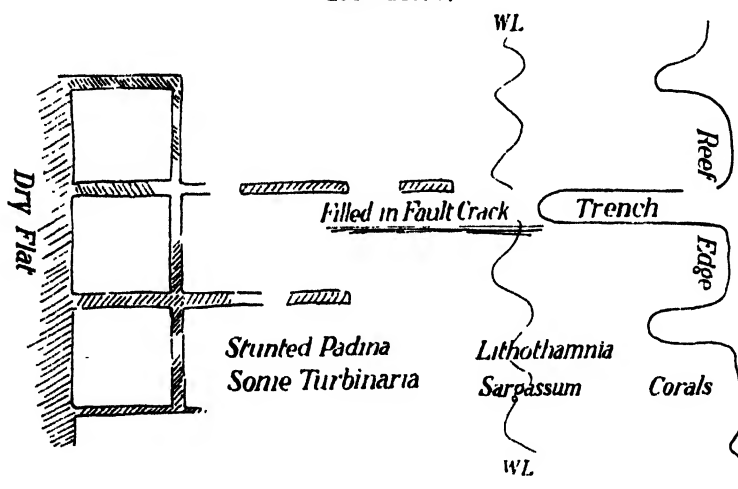


Diagram to explain photograph no. 0, Pl. 3, showing three square pools enclosed in dyke ridges and the connection between these and a trench in the reef-edge.

also shows the relation of one of these old cracks to a fissure in the apparently outgrowing reef-edge, clearly showing that these fissures are the result of the opposite process, that of erosion. This is found to be the case wherever these shore-reefs are continuous with shelves cut into older rock, as on the west side of Tahara Head, and at Atiue. I am able to illustrate this latter case, the photograph showing how a fissure in the "growing" reef edge, with its sides overhung by growths of lithothamnium and corals, is continued into the dead concrete-like rock shorewards, where there has never been any growth *in situ* (fig. 9, Pl. 37).]

Reefs of this peculiar material, once subterranean, are frequent along the north-east coast, where the old maritime flat has disappeared. The filled in cracks of the barrier edge are not so conspicuous as in this case,



but are clear enough, as shown in the photograph of the Atuaie reef (fig. 7, Pl. 37). They are also distinct off Papeari on the south coast, and on the high part of the reef-edge south of Punaruu, which has already been referred to. The reef rises by broad steps to the highest point, each step a shallow pool. Familiarity with those more conspicuous cases enables the less obvious to be recognized, and traces of these fractures are general wherever the reef-surface has not been cut away too deeply, as it has been over so much of the circumference of the Island. It seems likely that the trenches in the outer slopes are due to the widening by the scour of the surf of the cracks which run in that direction, for which some further evidence will be given in describing the passes.

It is hardly necessary to state that these little ridges separating adjacent pools are not due to recent growths. The reader will be reminded of the curious concentric basins on one of the Tongan reefs, described by Lister \*, and photographed, without any reference in the text, by Agassiz. These are due to the growth of lithothamnia, and such cases have been kept in mind when examining the above described ridges.

Faulting in the large scale in the island itself has been described in my earlier paper. The discovery of smaller faults is difficult in the irregular formations of a volcanic cone, but circumferential cracking is often shown by dykes projecting into the sides of valleys. That photographed on Pl. 37. fig. 10 is in Papetoai Bay, Moorea Island, but was taken to illustrate what may be seen frequently in Tahitian valleys.

THE PASSES may be divided into three different categories :—

(1) Deep passes such as that of Taunoa, in which the bottom of the pass is at or below the bottom of the lagoon.

(2) Shallow, such as that of Papeete, where the bottom of the pass is above that of the harbour. In other cases it is even higher above it.

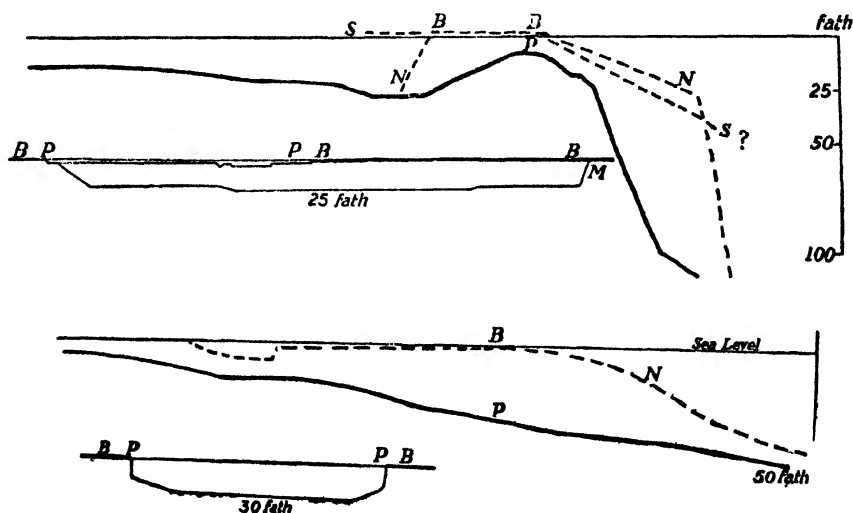
(3) Broad gaps, such as that of Punaruu and Pa'ea on the west coast, and that on the middle of the east coast, which last, perhaps, ought to be made a fourth category.

It is possible that these have been made in three different ways ; the deep and shallow passes are obviously quite different, and there is difficulty in imagining that the former can be derived from the latter by progressive deepening, since broadening seems to be going on relatively faster. There is real correspondence between most of the deep passes and the larger valleys, though valleys are so numerous that one might be found for every pass without real connection. The pass into Papeete Harbour is obviously such a case ; it is not possible to imagine that so shallow a notch on the reef, only a little over a quarter of the enclosed lagoon, could be in any way connected with the restriction of coral growth on the bottom of the drowned end of the Reine valley. (It is not necessary to discuss the idea that the mere outflow of fresh water has killed the corals and so kept

\* Lister, J. J., Q. J. Geol. Soc. 1891, p. 590.

open the pass, nor to correct Dana's remarks and plan.) In general, while the drowned valley theory might apply to the deep passes, it cannot to the shallow, which are due to the local breaking down of the originally continuous reef-edge in the ways already described. Such deep passes as that of Taunoa might be of such origin, if we had clear evidence of drowning, but to take the passes themselves as such evidence is to argue in a circle. Three rivers flow into the bay near the Taunoa Pass, one of which, famous in the history of the island and for the adventures of "Pierre Loti," is one of the major streams of the island. The wanderings of the mouths of these streams have been described in my paper, above quoted, on coastal topography, the third now having its outlet beyond the eastern point of the bay.

TEXT-FIG. 10.



Diagrams of shallow and deep Passes, the upper pair giving contours of Papeete, the lower Taunoa Pass. In the larger diagrams the thick lines show the bottom slopes from the harbour seawards through the Pass (P), the broken line the reefs at the sides of the pass, (N) the reef to the north, (S) that to the south (in the figure of Papeete only, soundings being wanting on the south side of Taunoa Pass). (BB) is the portion of the reef which is above sea-level—the barrier, (M) the reef of Motu Uta. Vertical scale twice the horizontal. The smaller figures represent the passes as they would appear were the water removed. Looking seawards from the bottom of the harbour of Papeete the observer would be faced by a cliff 150 feet high in which an inconspicuous notch would represent the pass; in Taunoa Harbour the view would be clear to the open sea. True scale.

Considering the parallel and independent courses of the streams of Tahiti to the point at which they emerge upon the maritime flat, it seems highly unlikely that, if the island had been once at a higher level, these three ever reached the sea by a common mouth.

There are features common to every pass. All show signs of great erosion, but whether widening or deepening is the more rapid I cannot say, although the evidence of widening is the more conspicuous\*. The sides are always precipitous and more or less undercut, and the bottoms, of the shallow passes at least, quite bare and obviously under rapid erosion†. Scattered corals occur on the sides, many of which have long been dead. The chart soundings show how steep-sided are all the passes, but cannot, of course, show the undercutting nor the vertical cliffs, which are so impressive in actual sight. At the east end of the Papawa barrier, for instance, when the outrigger of my canoe was over the edge of the shelf, which was 12 feet under water, the precipice under the canoe itself was 66 feet deep, and at the Taunoa end of the same reef, where the shelf was 9 feet under water, the precipice was sheer for another 90 feet. The same thing is seen in Papeete Pass, which is so shallow in comparison. The point to be emphasized is that the soundings do not indicate a talus slope, however steep, but sheer cliffs in solid rock, and universal undercutting.

A peculiarity of some passes which may be mentioned, though it will be seen to have no bearing upon their formation, is the existence, on one side only of the passage, near its mouth, of considerable areas of pure *Porolithon* rock—e.g., on the southern sides of Atiue and Pa'ea, the eastern sides of some of the passes off Papéari. The first is shown on Pl. 38. fig. 13 and appears a structure of importance, but when in the pass on a day of some surf, it was seen, when the canoe sank down between two waves, that this lithothamnion rock is only a capping two or three feet thick, the rest of the reef below it being of coral. The material also is fragile, so much so that it could not survive in an exposed position, and my samples of this rock needed careful handling to get them home intact.

The peculiar cliffs in the as yet unbroken reefs, which have been described, indicate the possibility that passes may originate from this undermining of the reefs, local exaggerations of the general destruction, independently of any other cause. Less easily accounted for is the fact that shallow passes are often cliffed along their lagoon sides, indicating possible undermining and collapse from the lagoon. The pass of Tahuru‡, near Tautira, which is particularly shallow, among many others illustrates this feature, and soundings at close intervals through a series of passes might further elucidate their peculiar features.

\* The passes examined in detail are:—North Coast: Papeete, Tuanoa, Papawa. West Coast: Taapuna, Punaruu, Atiue, and Pa'ea. South coast: Two to the eastwards, Taiaapu: Tautira, Taone, and Vaionifa. Also three in Moorea.

† Local opinion holds that Papeete Pass is shoaling by coral growth. There is no evidence for this; the fact that it is barely deep enough for large vessels is all that has given rise to the idea.

‡ This is the pass which so nearly brought Capt. Cook's expedition to disaster, perhaps more nearly than the great captain himself realized. Knowing the place his account "brings the heart into the mouth."

Or, again, the shallow passes may originate at the points where wider trenches than usual cut into the reef, or where a series of trenches penetrate the crest and drain the *Sargassum* area. Once the raised edge is broken, however slightly, the rush of water from the lagoon would quickly enlarge the cut, as a small leak in a dam may bring about catastrophe. In most cases such cuts are self-healed by the growth of coral, so that, as a rule, they initiate only the general lowering of the crest and its conversion to the lower, soft, and living edge, but larger breaks would soon cut a pass. These alternatives account for the rarity of intermediate conditions between low reef-edges and shallow passes, though such occur on the north side of Tiarapu. If we allow that the deep passes are of the same sort as the shallow, especially owing their depth to the same erosion longer continued, the problem of the passes is solved—all are due to the general breakdown of the reefs, which is everywhere in progress. To the writer the distinction however, seems real, and just as, in spite of the evidences of deep erosion in certain of the lagoons, he is driven to postulate deep fissures as their first origin, so in the case of the deep passes, he feels that the deep radial cracks, which necessarily follow from the suggested circumferential crackings, are necessary postulates.

THE CAUSE OF THE CHANGE IN THE VIGOUR OF CORAL GROWTH is not easy to determine. One factor which is immediately seen is the conversion of hard basalt into red clay-like laterite, which is universal on the lower slopes, and makes conspicuous red patches among the fern, especially above Papeete. From this quantities of red mud are poured into the sea after every rainstorm, which probably was not the case in the early days when the reefs were growing\*. This cannot be the whole story; the north coast, on which the effect has gone farthest, is not the most rainy, and many corals are surprisingly resistant to heavy deposits of this mud. It may be due to changes in the coral fauna, which, as will be shown in a later paper, is restricted in the number of species present, not only for the geographical reasons usually given, but by some obscure ecological factors as well. It may be due to changes in the balance of life between the corals and their organic environment, or to changes in the sea-water over the reefs and in the lagoons.

Is this cessation of reef growth peculiar to Tahiti, or is it possibly world-wide? Is the present age of corals passing or past? In 1902 the writer described the great reefs of Zanzibar and East Africa as dead, mere shelves

\* Professor W. M. Davis suggests that the trapping of alluvium in valley mouths as the island subsided gave the corals their opportunity. Against this it is to be noted that the postglacial fall of ocean-level has resulted in most of the heavy alluvium being nowadays left on the inner part of the maritime flat, and it is only now, and not in all cases, that the rivers are beginning to carry heavy alluvium to the sea. The red mud was probably not abundant in the days to which Professor Davis refers.

cut in the great raised reef which forms all these coasts\*, and the cliffs round all atoll rings suggest that these, too, are undergoing erosion rather than growth. In 1900 Gardiner found that at one point, at least, of the reef of Minikoi there has been little, if any, extension of the reef seaward since the fall of ocean level which converted most of the reef into land †, and in 1905 described the great lost reefs round the Seychelles ‡. Fryer, in 1908, found that the reefs of Aldabra had been killed by the sand deposits of their own decay †, while, to pass from the Indian Ocean back to the Pacific, in 1917 to 1920, Mayor showed that the shelf round Tutuila, Samoa, was once a barrier reef §. In all descriptions of coral reefs the impression left is the extremely small amount of growth to which these immense structures are attributed. Is it possible that most of them were built under conditions which no longer hold? This possibility introduces another complication into this fascinating study, and makes it desirable to obtain more information in this case, by boring to determine whether the fauna has been different in the past (as well as to obtain definite evidence of the depths of the deposits in the valley mouths), the state of the foundations of the reef and their depth, and by a much more thorough study of coral ecology than has ever been possible by expeditions lasting only a few weeks.

#### TAHITI—SUMMARY.

The reefs were continuous from shore to ocean, and the lagoons have been excavated in them secondarily. Consideration, of the western reefs especially, induces the writer to postulate annular cracking as the first origin of the lagoons; this is necessarily accompanied by radial cracks which formed the rudiments of the deep passes. Traces of such faulting are to be seen in many places on all reefs. These cracks have been widened by erosion, the present rapidity of the process indicating that this has gone on to a great extent. Some lagoons are probably filling in, others, on the east coast, are still being excavated, and have been made particularly wide and open, their lagoon-reefs having been reduced to pillars.

The reefs are no longer growing seawards, but are going back, in spite of the coral growth which abounds on the upper 10 fathoms of their ocean slopes. On the north and east coasts this has gone so far that the reefs are under water, with the consequence that the flat has largely disappeared, the cliffs drop into the sea, and this part of the island is uninhabited. This coast resembles those of the Marquesas, to which form the whole is tending.

\* Crossland, C., "The Coral Reefs of Zanzibar," *Proc. Camb. Phil. Soc.* xi, vi, p. 498 (1902).

† 'Fauna and Geography of the Maldives and Laccadives,' *Camb. Univ. Press*, 1918.

‡ "The Percy Sladen Expedition to the Indian Ocean," *Trans. Linn. Soc., Zool.* xii, 1907 to 1909.

§ *Carnegie Inst. Wash. Mayor Memorial Volume*, vol. xix, 1924.

The Passes fall into at least two categories, the deep and the shallow ; the latter are local exaggerations of the general process of reef decay, on the surface and by submarine erosion, both on the lagoon and ocean slopes. Possibly the deep passes are derived from the shallow by further erosion.

The weakening of coral growth which has caused the cessation of that of the reef may be due to the decay of hard basalt into the clay-like laterite, which is poured into the sea in quantities in floods, but the writer thinks that this is not all. It is suggested that the age of corals is past, not only in Tahiti but in many parts of the world, instances being the dead reefs of Zanzibar and elsewhere, and the cliff which generally surrounds atolls, at about 50 fathoms below the surface.

#### COMPARISON WITH MOOREA AND RAROTONGA.

The main interest of the other islands, Moorea and Rarotonga, is through comparison with Tahiti. Both, like Tahiti, are volcanic, greatly eroded, circled by a low maritime flat and coral reefs, but with this similarity of general plan are significant differences. Moorea is the next neighbour to Tahiti on the north-west, separated by only 10 miles of sea ; Rarotonga is the principal island of Cook Group, 630 miles to the south-west.

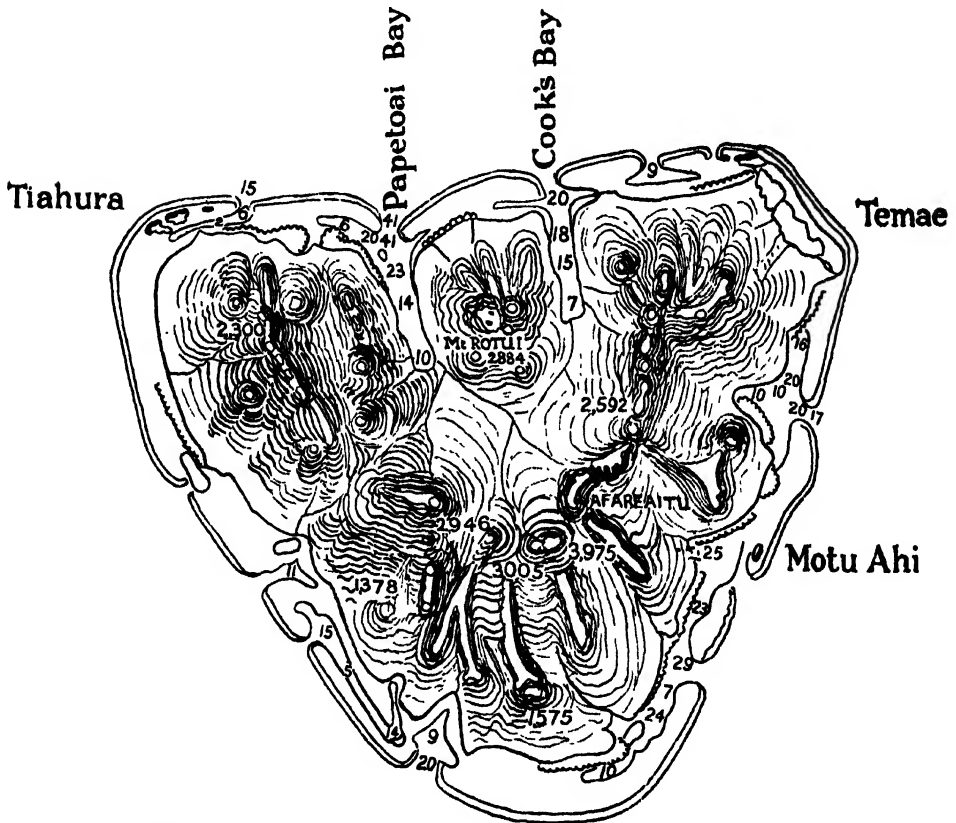
**MOOREA \*.** The rugged, even fantastic, outline of Moorea (Pl. 38. figs. 13 & 14) alone shows how much further erosion has proceeded, and on nearer approach the widely open valleys make another contrast to the deep ravines of Tahiti. At least twice as much has been removed from the original cone as in Tahiti, so that not more than one-fourth of the original volcano remains, and this is probably too conservative an estimate. As the lower island means a lesser rainfall, and its small size and short streams mean less erosive power in proportion to the precipitation, erosion on Moorea acted at a much slower rate. The island must therefore be from four to six times as old as Tahiti. Its reefs have, however, nearly the same breadth, from which it appears that the period of reef growth has been the same for both islands ; they began together, and are now at the same stage of recession. The process by which most of the mountains of Tahiti end in knife-edged ridges has gone so far in Moorea that many of its mountains are quite wall-like, mere skeletons. The fantastic peaks at the head of Papetoai Bay, for instance, have exactly the same outline, detail for detail, when seen from the southern valleys, the sloughing away of mountain sides described in Tahiti having proceeded equally from the crater valley and from the southern cliff ended valleys. Moorea is thus a more picturesque island than Tahiti, not only because the mountains are even more wildly shaped, but because they

\* The older name, used by Cook and the earlier visitors, is Eimeo. Native custom demanded the change to Moorea, but Eimeo is still in use.

are so much more accessible to view through the widely opened valleys. Further, the crater valley, so inaccessible and so choked in bush in Tahiti, in Moorea is reached by two fjords which run in from the north coast and penetrate the crater wall, giving incomparable views of the central mountains to which the calm water and lake-like shores provide the ideal foreground.

The triangular shape of the island and its excentric crater valley, the bays

TEXT-FIG. 11.



Island of Moorea showing excentric crater, opening to north by two fjords, the widely open valleys, continuous reefs, and partly filled lagoons. "Raised" coral on islets of north and east coasts shown as black dots.

of the south and east coast, are other differences from Tahiti, the explanation of which becomes clear when the cliffs of the island are considered (Pl. 38. fig. 12 and Pl. 39. fig. 18). As in Tahiti, these were cut by the sea before the island was protected by reefs, and they are now separated from the lagoon by the maritime flat. They are evident all along the north coast, though

more disguised by subaerial denudation than in Tahiti, and along the northern parts of the east and west coasts. They are absent altogether from the southern half of the island, where the spurs descend without truncation to the sea-level, except for little cliffs on the southern apex, which are obviously cut by lagoon waves and currents. They reach their maximum height of 500 feet and more round the north-west corner of the island. Now this is the exact reverse of conditions in Tahiti and Tairapu, where the cliffs increase in height regularly to the south, from which direction the great waves of storms of southern latitudes beat upon the island. It can only be explained by a deep tilting of the island to the south, and a little to the east, which has submerged the southern cliffs, leaving as visible evidence the drowned valleys of this side of the island. The two fjords of the north coast cannot be drowned valleys also, as this would involve a deeper submergence to the north than to the south, which would have carried the northern cliffs also below the sea. The high cliffs at the north-west corner of the island are not wholly of marine origin, but represent part of the fault scarp formed when this northern part of the island foundered, leaving the crater excentric and forming the straight line of the north coast. Probably in connection with this great movement the two fjords originated by explosions from the crater, and are not drowned valleys at all; indeed, it is difficult to imagine how two rivers could drain the crater to form so nearly equal valleys—without the nicest adjustment one or other would capture the whole drainage and form a single large valley.

Professor Davis differs from this interpretation of the island's structure \*; the two fjords to him represent drowned valleys and indicate a nearly equal submergence of the island on all sides. The fact that the cliffs remain above water on the north coast and reach their maximum height on the north-west, he explains by the longer exposure of this corner of the island to the action of the waves, through delay of coral growth, due to the westward drift, of the alluvium from the valleys which are now the fjords. This would involve effects which would be at once visible on the chart—(1) considerable recession of the shore line west of the fjords, (2) the reefs of the north coast should decrease in breadth over their western two-thirds. As the north coast is remarkable for its straightness and the even breadth of its reefs, Professor Davis's simple and ingenious explanation seems to fail.

Later than all these changes of level came the general fall of the ocean. As we have here no exposed cliffs of hard rock, the evidence of this fall, which is given by the shelves at the base of such cliffs in Tahiti, is here absent, but we have abundant evidence on the reefs and in the existence of high-level beaches. Moorea possesses small land surfaces of raised coral rock, occurring as small flat islets in the outer part of the lagoons. These

\* 'Nature,' vol. cxx, p. 330, Sept. 3rd, 1927.



are all 2 feet above the sea, whether at the east or west end of the north coast or halfway down the east, but, as some bear massive corals in position of growth projecting 4 feet higher, the total retreat of the sea comes to 6 feet, as in Tahiti. There are also remnants of planed-down reefs near the shore and in stream-beds occurring at the same level—i. e., a foot or so above present reef levels, in the fjords of the north coast and one of the drowned valleys of the south.

It is clear that all these changes in the island itself have had no effect upon the forms of the reef. Parts of the reef are "barriers" separated from the shore by deep channels on all coasts, other parts are "fringing," equally wide reefs enclosing no water deeper than 3 to 6 feet between the raised edge and the shore, even through a long stretch of the deeply submerged southern apex of the island. It may be that the reefs grew up, or at least took their present form, after the tilting movement was over; but, at the same time, I can find no evidence that submergence of a growing reef *could* convert it from the fringing to the barrier form. On the contrary, the submergence of the edge of a reef would alter the deposition of wave-borne débris from its outer to its inner side. So long as the reef reaches the surface the greater part of its débris is carried downward on its outer face by the drag of the surf, but as soon as the reef-edge is below the surface, whether by submergence or the upgrowth of a band of coral at a distance from land, the greater part of the loose material is carried *over* the reef and deposited on the landward side. This is well shown in Tahiti, where surface and submerged reefs can be directly compared. In the former the amount of débris carried over the lagoons is comparatively trifling, in the latter the inner slopes consist of large amounts of coarse coral débris. It makes no difference to the argument that these reefs owe their submergence neither to subsidence nor to youth, but to the removal of the upper 5 fathoms or so by erosion. Given the production of coral in such quantities that the reef is growing, instead of, as in the present case, going back, it seems inevitable that the space within the hypothetical offshore bank would be filled in. The second observation is the peculiar abundance of coral growth *over the surface* of the shore-reefs eastward of Papeete. Elsewhere (in Tahiti and the tropics generally) coral growth is abundant only in a band round the edge of the reef, but in this locality it grows thickly over nearly the whole surface. This is due to the strong currents which carry away all débris, and keep the surface always below water-level. Subsidence of an oceanic island would reproduce these conditions, resulting in wide beds of strongly growing coral, almost continuous from shore to ocean. On the reef's reaching the surface all this is changed, and the excavation of a boat channel is begun. It is to be remembered that, owing to the fall of the sea-level connected with the last glacial change, the larger reefs of the world did not merely reach the surface, but actually emerged, so that the ecological changes within them

were the more complete. There are few reefs, even of these apparently living, which have not had a geological history of some length\*, and the original form and conditions of growth of most reefs is a matter of deduction, not of direct observation.

What are the differences between the reefs of Moorea and Tahiti due to the almost entire absence of alluvial outpourings in the former? As regards the outer slopes, little, if any; the advantage to coral growth is conspicuous only in the lagoons and on the maritime flat. In the former are abundant growths of clear-water corals (dense beds of corymbose species of *Acropora*, for instance, occurring close inshore), and the sand produced by coral decay is clearly filling in the sides and inner ends of the lagoons. The maritime flat, too, is composed of coral sand etc. to a far greater extent than in Tahiti, a broad band of this formation practically encircling the island, and, the supply being still ample, we do not find in Moorea the rapid erosion of the flat which is so constantly in evidence in Tahiti. Most of the flat at the north-west angle of Moorea is of white coral sand, without even discoloration by volcanic alluvium, and the flat is absent only from short distances on the southern apex of the island. Here three low spurs, which, like the others hereabouts, have no old marine cliffs at their ends, descend straight into the lagoon, a little halophilous grass at their bases perhaps representing a once existing flat. As on the south coast of Tahiti, the heavy surf from the south has removed, or prevented the formation of, much of the flat, and has given rise to enough sea in the lagoon to cut little modern cliffs in the spur ends, though immediately round the corner to the west flats of coral, mixed with some alluvial sand, appear in their usual proportion. Just west of Papetoai are bays containing flats of red mud, but even these, on digging into them, are found to contain a high proportion of coarse calcareous sand.

The outer slopes of the reefs, on the other hand, are much the same as in Tahiti, but the ravines, where they are distinct, east of Papetoai on the north coast, are less deep. Elsewhere the slope resembles that of the west coast of Tahiti, coral is generally abundant, the trenches, though numerous and containing stones (some of which apparently are basaltic), ending at the edge of the shallow surf-cut slope or continuing as shallow depressions full of stones and coral debris. At the bottom of some trenches were noted cracks partly filled with sand, and sand is frequently seen in hollows and lines at, and below, 10 fathoms. On the north coast, the first, and more gentle, slope is exceptionally wide, so that the bottom is visible to passengers by schooner for all this part of the journey between Papetoai and the east corner of the island. Coral growth is perhaps more abundant than in Tahiti, but the species are the same; there is no better development of

\* Dr. P. Marshall states that the reef of Mangaia has been in continuous formation since the Miocene (Bulletin 36, Bishop Museum of Honolulu).

Astreans, and it ends at the same depth. Yet the most barren area I have seen in any of the islands is found on the north-west corner of the reefs of Moorea, where even the usual crust of lithothamnia is absent and there are patches, several yards across, of a dark green seaweed (*Codium*), which I have not seen elsewhere on the outer slopes, nor anywhere in such abundance. There is more sand here also, doubtless in connection with the accumulation which forms the Tiahura Islets on the edge. Near here on the surf slope was found peculiarly direct evidence of erosion of this surface. It is full of holes and grooves, an inch or thereabout in diameter, careful examination of which showed them to be the tubes of the mollusc *Magilus*, laid bare by the removal of the coral in which they were originally embedded.

The reef-edge is generally low, having reached the third stage described for Tahiti, in which the edge is scarcely above low-water level. Mr. Trower, of Papetoai, informs me that under exceptional conditions of weather, the edge off the Tiahura Islands is laid bare, and his photograph shows a level expanse, similar to the low edges of Tahiti. Farther east, however, the edges consist of a band of coral, the outer part of which is consolidated by lithothamnia, but, as this will not grow on the inner part, it gives place to a bed of separate corals. At first these are close enough together to make walking upon them possible, but further lagoonwards they thin out into scattered colonies, as the water deepens, only the *Porites* heads and scattered clumps of other corals of the usual submerged flat remain. There is a little brown weed about the outer band, but no continuous big beds of *Sargassum* and *Turbinaria*, as in Tahiti. As the edge is so low, there is no upthrow of solid spray after a wave has broken, and, using this as an indication, it appears that the edge is low almost everywhere except just round the north-west angle of the island. The reef off Afareaitu, on the west coast, is similar to the above, but the first slope is narrow and rather bare of corals, while the steeper slope beyond is thickly covered, this growth extending as far down as could be seen. It is clear that the recession of the reef is not so evident as it is in Tahiti, but, as will be seen later, the proof derived from the traces of erosion of the original high-level reefs is even more complete.

The Passes, like those of Tahiti, are of two kinds, deep and shallow. All show marked signs of rapid erosion of their sides, and in the shallow passes erosion of their bottoms is clearly seen. The difference between the slopes to lagoon and ocean on either side of the shallow passes is marked, the former being often the steeper, and indicating that the breakdown of the reef-edge, which formed the pass, may have been initiated from the lagoon side. The three passes on the east coast, on which side of the island, as in Tahiti, the lagoons are the most deeply excavated, show this phenomenon most clearly. I examined Tupapaurau Pass, where the bottom is easily seen in detail, and is a bar of barren, eroded, coral rock, right across. The sides are cliffed as usual, in one place on the north side is a talus of slabs, *Acropora* stumps,

above the cliff at the lagoon end, which, as it begins at the top of the reef, is due to breakdown, not to accumulation. Taotoi Pass on the north-west coast is complicated, not the simple affair shown on the chart, and is really deeper inside than out. The outflowing current is so strong as to be visible for several hundred yards out to sea in calm weather. This is due to the surf on the western reefs, the overflow from which escapes this way, *via* the channel behind the Tiahura Islets. A rock on the east side of the pass, rising abruptly from the bottom of the pass to near the surface, obstructs this current, which flows over it with a distinct fall, like a rapid in a river. As the current impinges more on the east side of the pass, this is all cliffed, going down in irregular steps, while on the west side are sand slopes. The conditions strongly suggest that the pass was formed by coalescence of a series of large trenches; its irregularities forbid the idea of erosion acting alone, and it is far too narrow and shallow to be the remains of a drowned valley.

The evidence of faulting in the reefs has not been preserved on the edges, as these are practically all cut away and replaced by growing coral. In the sheltered water of Papetoai Fjord is, however, the most perfect example of a reef dyke I have seen anywhere (Pl. 38. fig. 14). The fringing reefs of these fjords are now dead, and have largely decayed away, even the outlying reef north of Taiarii Point is barren, and eroded a fathom or two below sea-level. The remains of the shore-reef southwards of this point are deeply fissured and undermined: where it is broken down masses of *Porolithon* form rounded heads from 4 to 6 feet each way, but these, so solid in appearance, are in reality very friable, much weaker than the small masses of branched *Lithophyllum*, which occur here and there. Through this reef, on both sides of the bay, projects a dyke of harder rock, 6 inches or so higher than the isolated *Porolithon* masses can grow, and planed off at this level. Its course, in spite of some short right-angled turns and seaward buttresses, is parallel to the shore, and it is often continuous like a little wall, 2 or 3 feet high, according to the depth of the reef pools alongside. The rock is so hard that I expected to find it a concrete containing basaltic pebbles, but, though it is so near the present shore-line, it is of pure coral. It must have been formed before the debris of the cliffs had spread so far over the reef. Shorewards remnants of the original high-level flat are to be seen.

Of "negro-heads" on the reef edge there are none. Certain stones on the west side of the Pass to Cook's Bay were noted by him, and have native names. They are the property of certain families, but whether because they are the last relics of a reef islet, or because they once had a religious significance, I do not know. They must have been much more conspicuous in Cook's time, but there is nothing now to distinguish them from the other pieces of coral which tend to collect in similar positions, and may be the beginnings, or the last remains, of a reef islet.

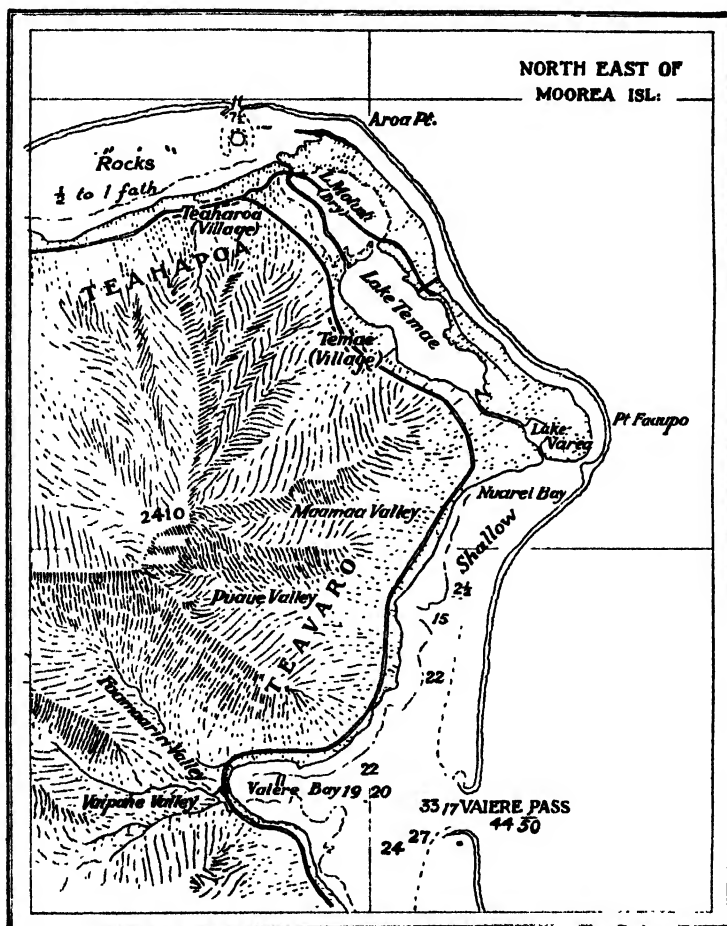
Flats of elevated coral rock exist on three areas of the reef, at the east and west ends of the north coast and halfway down the east coast. All are at a level of about 2 feet above the sea, and are undercut on the seaward sides; on the north coast both extend for some distance in the direction of the centre of the island as broken elongated spits of rock, and obviously they once encircled the whole coast\*. The greater part of each is buried on its landward side by an island of coral débris, those of the north coast being reef islands strictly comparable to those of atolls, that off Afareaitu on the east coast, being well within the pass and away from the reef-edge, is like the reef islets of Tahiti. That these flats, composed entirely of broken coral, cemented together, are not beach deposits is shown by their being *horizontally* stratified, the upper stratum being 1 foot thick; but conclusive, and very definite, information of their origin is given by scattered hummocks of rocks which rise above the general level to a height of 2 to 4 feet (Pl. 39. fig. 15). On chipping with a hammer, these are found to be colonies of *Porites* in the position in which they grew. Some have their bases buried in the coral of the flat, others are raised on pedestals 2 or 3 inches high. It is quite evident that we have here a portion of the submerged flat of the lagoon at a level of 6 feet above its original position, and the hummocks of *Porites* correspond exactly to those now growing in the lagoon alongside. It is amazing that this should be so entirely unaltered after the lapse of 3500 years. I am familiar in the Red Sea with elevated reefs, on hill-tops even, in which every coral, and still more every shell, is readily identified with species living in the adjacent sea, some of the latter retaining much of their colour, but in their case the original surface of the reef was blown away as dust hundreds of years ago, whereas here in Moorea we have the actual surface of the floor of the lagoon flat with the loss of only a few inches. I may say that this conclusion seemed to me incredible, and was accepted only after repeated visits to all three localities. Not only is the rock identifiable as the floor of the submerged flat, but it is also certain that it is the *outer part* of this flat, and, as it is now but a few yards from the barrier edge, it is clear that there has been no extension of the reef since the change of ocean-level took place, or, if extension did occur, it has since been wholly lost.

The existence of these flats, as narrow bands parallel to the reef-edge, is at first puzzling, since the whole flat must have emerged together. The explanation is found in the peculiar action of spray upon coral, which recrystallises and cements it into hard rock, strengthening it against its own destructive action. This process having been confined to the outer part

\* The rock flat at the eastern corner of the island, off Temae, was used by a party from Captain Cook's expedition as a second base for observations of the Transit of Venus. It was recognised by them as being of coral, but on the expedition of the U.S.F.S. 'Albatross,' 130 years later, the blackened coral was reported to Agassiz as being volcanic.

of the emergent mass, that alone has survived, the unconsolidated inner parts having been removed by the erosive and solvent actions of the lagoon, the powerful effects of which we have already seen. One finds that this is actually the case, the inner sides of the band of rock being far less consolidated, and consequently between the two islets of Tiahura \*, landwards of the

TEXT-FIG. 12.



North-east corner of Moorea, Temae Island, and Lake. "Raised" coral black.

nearly continuous seaward raised coral, *Porites* blocks lie loose, their unconsolidated foundations having been removed (Pl. 39. fig. 16).

The existence of the coral islands on the reef-edge seems to be dependent

\* They have separate names, but as they are really one structure I simplify my account by using that of the larger for both.

upon the existence of the raised coral rock, here and at Temae at the opposite east end of this coast. It is described also in the connection with the reef islets of Maiao "half atoll" 50 miles west of Tahiti by Chubb\*, and by both of us on the atoll of Napuka†. Its existence in the other Society Islands is not certainly known, but Mr. Trower, of Papetoai Hotel, who knows the Tuamotu Atolls exceptionally well, tells me that what rock there is in these atolls is quite similar, and the same height above the sea. At the same time, parts of the Tiahura and Temae islets certainly existed before the fall of ocean-level gave them this protection, much of them corresponding to the old beach deposits of Tahiti. The most striking case is on the seaward side of the western Tiahura islet, where erosion has formed a cliff 8 feet high above the beach, which is 3 feet high. This consists of quite unconsolidated strata of coral gravel and coral sand, the coral fragments more or less worn, and evidently thrown up by the sea. None of it is dune-formed, the top layer is of gravel, and no wind-blown deposits were seen anywhere in either island, and even the finer sand of the opposite mainland contains larger fragments immovable by wind. Other parts of the island may have been made by hurricanes at present sea-level, but storms of any lesser strength can add to the modern beach only. A section of the island always shows an older beach inland, well away from any action of the sea at its present level. The distinction is, perhaps, most clear at the south-eastern side of the large island of Temae, where the old beach deposits flanking Nuraei Bay pass into it (text-fig. 12, p. 613). Here, a considerable addition has been made in recent times at a distinctly lower level.

Temae Island (Pl. 39. fig. 17 and text-fig. 12) is fundamentally similar to Tiahura, but differs in that at either end the accumulation upon the reef extends to the main island, thus cutting off a portion of the lagoon, the water of which has become fresh and is known as Lake Temae. To this the island slopes down exactly as that of an atoll does to its lagoon. There is no coral on the landward side of the lake, and from the road nothing can be seen of the water, which is hidden by reed-grown swamps. The coral rock is confined to the western corner of the islet, to the east and south there are developments of beach rock, distinguishable by their dipping strata, and the old lagoon floor disappears. As at Tiahura, old beaches may be distinguished above the modern one, but in all the coral is far less altered by solution than on the atoll of Napuka. This is probably due to the comparative absence of spray in the Society Islands. The Tuamotus are well known to suffer much worse weather than visits the Societies. Not only are these islands structurally like those of atolls, but they are sharply distinguished by bearing

\* Chubb, L. J., M.Sc., and W. C. Smith, "The Geology of Maiao," *Q. J. Geol. Soc.* lxxxiii. 1927, p. 342.

† Crossland, C., "The Expedition to the South Pacific of the S.Y. 'St. George,'" *T.R.S.E.*, lv, pt. 2, 1927.

the atoll type of flora, which is quite absent from the main islands and the reef-islets of Tahiti. This is easily explained in the case of Tahiti, where erosion on the one hand and coconut planting on the other might have exterminated it; but Moorea, with its coral shores and less active population, might be expected to retain it. One bush of *Tournefortia* is all of this very interesting and distinctive flora which I have seen on the main island, which has its own strand flora of large trees, *Barringtonia*, *Calophyllum*, *Hibiscus*, etc., and it is clear that the atoll flora requires not only a shore free from volcanic alluvium but also composed of coarse material, so that the only Tahitian specimens of *Tournefortia* occur on Motu Au off Point Venus, where alone coral shingle abounds. *Pemphis* is still more restricted in

TEXT-FIG. 13.

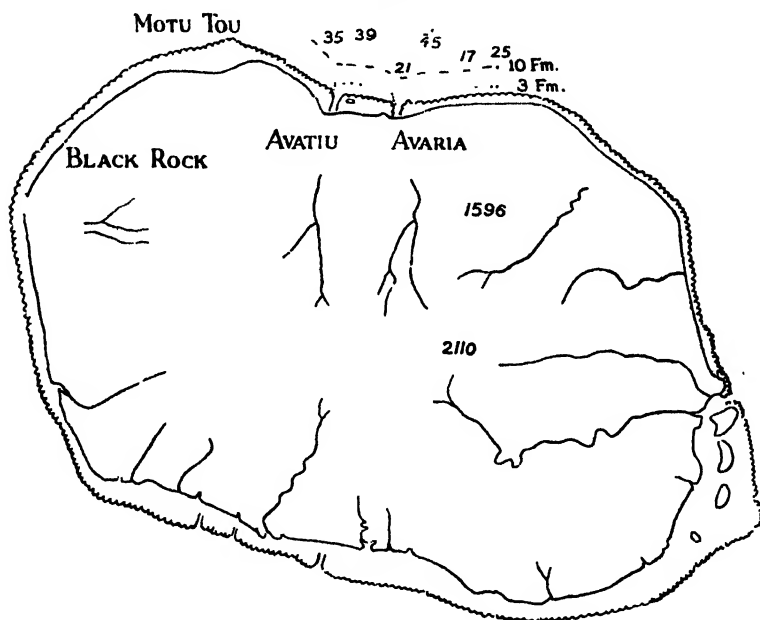


Chart of Rarotonga. Notice the gradual slope off the reef-edge and the streams which do not reach the sea. The Black Rock is the end of a basalt dyke which reaches the sea on both west and east coasts.

its habitat; it is to be found only on the bare rock below the beaches, the area over which the coral debris is swept in storms to form the islands! Among the casuarinas and pandani, etc., which form the jungle above the belt of *Tournefortia* and *Scaevola*, are many herbaceous plants which I recognized as having seen here for the first time. It is sad to see the last remaining forest of well-grown casuarinas, so different to their scraggy growth on the hills, being burned down to make room for the too ubiquitous coconut, a process which extends to the remotest of the atolls of Tuamotus,



The Maraes—heathen altars—of Moorea are interesting from our present point of view, in that so many demonstrate that even here erosion of the maritime flat is going on. That of Afareaitu is practically in the sea, while the paved court behind it is sunk into wet sand. The face of this altar, now scarcely more than a heap of loose coral, is peculiarly interesting in that its lower part has been consolidated in one mass by the cementing action of the sea. Further, we can date the beginning of the process, for its facing of volcanic stones was removed by Ellis in 1817 to pave his printing shop, and fallen pieces of this facing are enclosed in the cemented stratum. This process has therefore been completed in the short space of 110 years. On the other hand, the discoloration of the coral, which under the influence of rain and spray becomes coal-black, has not proceeded far, the coral of this altar being only grey. That of the flats of Tiahura, Temae and Ahi Islets is of a dark grey, not really black, while the coral of the old beaches is of a dark tint between the two, contrasting sharply with the dazzling white of recent beaches.

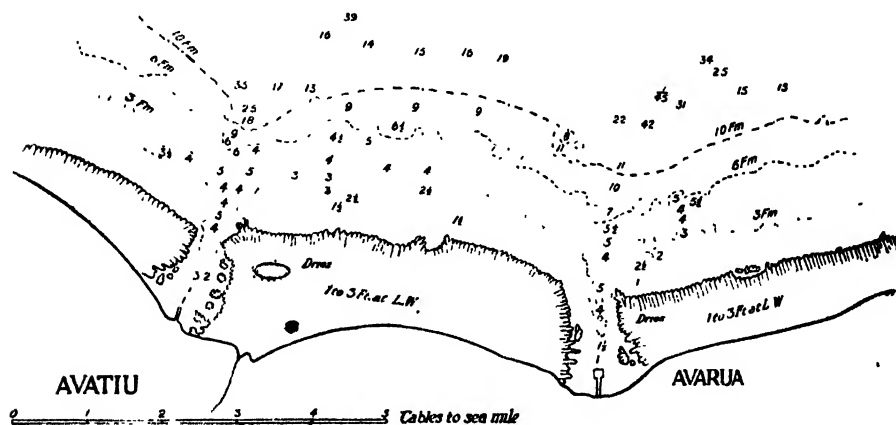
RAROTONGA, again, is a volcanic island, but both older and smaller than either Moorea or Tahiti, only 7 miles in longer diameter. Its old cliffs are doubtfully visible as steeper slopes where the spurs run down to the maritime flat. It differs from the other islands described in that the reef is fringing and quite narrow, but, fortunately for the commerce of the Cook Islands, there is a shallow shelf, 6–8 fathoms deep, outside the reef, upon which the mail steamer can anchor, and inlets in the reef just large enough to accommodate small lighters and tugs, and the island schooners. Such shallow shelves outside coral reefs are very rare; further examination of the extent and slopes of these might give valuable evidence of the history of both island and reefs. They more or less encircle the island, though not indicated on the chart, the “Pilot” states that anchorage can be got anywhere except just west of Avarua.

The first sight of the reef shows a marked difference to the others here described, and indeed to any others I myself have seen. In the neighbourhood of Avarua, the main landing-place, it is plentifully scattered with large stones, and backed by a beach of boulders (Pl. 35. fig. 2). These are all of coral, generally *Porites*, and those of the beach are well rounded by attrition, not pitted and edged by long exposure, evidence both of the plentiful supply of material and of the greater power of the sea in this more southern latitude. Not only is the supply of coral more abundant but the fauna is richer by those Astrean corals which are so strikingly absent from Tahiti; “Brain corals,” among others, are common and of large size. In correspondence with this we find that the shore-belt is not undergoing erosion, but rather appears to be spreading seaward, and I am told that a little reef island just west of Avarua, covered with a dense mass of *Scaevola* bushes and one *Casuarina*, has distinctly increased in size during the past

three years. This coral beach material forms a dry belt all round the island, which has been used as a burial ground from time immemorial, the roadside being lined with graves, some of ancient blackened coral slabs, others of imported marble with European inscriptions. Being sacred ground it is covered with splendid trees, members of the strand flora, a delightful change to the avenues of coco-palms, which, though so beautiful, are so universal elsewhere as to have become monotonous. Close to the sea is a belt of *Pandanus*, *Scaevola*, etc., as usual on recent strand of this formation.

Landwards of this belt the ground is lower and often swampy. An attempt was made to drain one of these marshes by cutting through the coral belt, but the ditch admitted sea-water, and was partly filled in again.

TEXT-FIG. 14.



The boat inlets of Avarua and Avatiu, Rarotonga, showing the reef as the summit of a shallow bank, sloping gradually to the 10-fathom line. Beyond this the few soundings there are show irregularity of the bottom, but there are no deep soundings.

It shows that the material is unconsolidated coral throughout, large pieces bedded together with sand, and gives the height of the flat above sea-level as 15 to 20 feet, so that, in spite of the freshness of the coral, much of it was evidently thrown up before the last fall of ocean-level, as in the case of the reef islets of Moorea. The swamp and the slopes behind it, at the base of the hills, are of volcanic alluvium. The exact correspondence of this formation with the lake of Temae, in Moorea, is striking. Just as in that case the greater part of the maritime flat is due to land-building upon the reef-edge, and it seems almost certain that the reef was originally as clearly of the "barrier" type as in Moorea; it has become "fringing" simply by the filling in of the lagoon and the extension of a band of reef debris almost to its edge. It would be interesting could evidence be obtained of the depth

of the original lagoon by boring or well-digging in the inner part of the maritime flat, and to discover how much of this filling was marine and how much alluvial. Judging from Moorea the former would generally preponderate.

Where the still-exposed reef is broader the shore is of coral sand, and the reef is hollowed out slightly; but I believe the channel could everywhere be crossed by wading, as where I saw it. The flat is barren of corals; it would seem that the origin of the boulder beaches is from the slopes outside its edge as at Napuka.

The reef and flat of Rarotonga may equally well be compared with those of Maiao in which Chubb\* describes the lagoon as largely filled in by marine material, completely so in places. The central volcanic island in this case is very small, about a mile across and 800 feet high, the alluvial supply from which must always have been small, and is now at vanishing point. It may also be compared with Mangaia, in the Cook Group, in which the coral band has been elevated to a height of 115 to 230 feet, which has been described by Marshall†, and with Rurutu‡. Elevation, followed by erosion of the filling material of the lagoon, would convert Rarotonga into one or other of these types.

#### MOOREA and RAROTONGA—SUMMARY.

Moorea and Rarotonga are like Tahiti in essentials, but both are smaller and older islands. In Moorea the excentric crater valley, straight north coast with old marine cliffs, the cliffless south coast with drowned valleys, indicate loss of part of the north side of the cone by faulting, and a tilting movement which has submerged the southern cliffs. The first origin of the lagoons may have been by a splitting of the originally continuous reefs, but the important fact is that the form of the lagoons is independent of the subsidence of the south coast. As in Tahiti, the most open lagoons are on the east coast, not the south.

In consequence of the small size and more mature erosion of Moorea and Rarotonga, the amount of alluvium now discharged into the sea is, in comparison with that of Tahiti, almost negligible. There is no visible advantage of this to coral growth in Moorea on the ocean side of the reefs, but in the lagoons it is considerable, the result being that in many places the lagoons are filling in at their heads, and the maritime flat is largely composed of coral and is not generally washing away.

\* Chubb, Quart. Journ. Geol. Soc. lxxxiii, pt. 2, p. 342-345, with sketch and diagrammatic section.

† Marshall, P., D.Sc., 'Oceania,' Handbuch der Regionalen Geologie, vii, pt. 2, Heidelberg, 1911, and Bulletin 36 of the Bishop Museum, Honolulu.

‡ Chubb, Quart. Journ. Geol. Mag. lxiv, Nov. 1927, p. 518.



CORAL REEFS OF TAHITI, MOOREA, AND RAROTONGA.





CORAL REEFS OF TAHITI, MOOREA, AND RAROTONGA.





6



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8



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CORAL REEFS OF TAHITI, MOOREA AND RAROTONGA







CORAL REEFS OF TAHITI, MOOREA, AND RAROTONGA.





CORAL REEFS OF TAHITI, MOOREA, AND RAROTONGA.



The evidences of the former higher ocean-level are (1) high beaches, (2) coral rock flats, as islets and parts of islets in the lagoons. (Such "raised" coral is not found in Tahiti.) As the reefs are continuous and there are no rejuvenated cliffs of hard basalt, no rock shelves at the bases of cliffs are visible. These rock flats are so well preserved as to be identified as the floor of the outer part of the submerged flat. As they still stand close to the barrier edge it follows that the reef has not grown seaward since the change of level took place, a conclusion already reached on other grounds in both Tahiti and Moorea.

At Temae and Tiahura in Moorea the reef becomes "fringing" by the formation of an island upon it comparable to those of atolls, and at Temae portions of the original lagoon have been enclosed as freshwater lakes. This explains the fringing reef of Rarotonga, which was originally a barrier, the lagoon of which has been filled in. In Rarotonga, as in Moorea, coral material is being added abundantly to the land, often in the form of rounded boulders. Such boulder beaches are found in Minikoi, Mauritius, the Seychelles, and the Great Barrier Reef of Australia, but have not been seen by the author in East Africa, the Red Sea, Napuka Atoll, or the Society Group.

The coral fauna is as restricted in Moorea as it is in Tahiti, in spite of the better conditions in the former island; but in Rarotonga the astreans, so conspicuously reduced or absent in the Societies, attain a normal development. The reef of Rarotonga is peculiar in having a shelf with 5-30 fathoms of water outside it, but soundings are absent for the most of the circumference of the island, and the form of the reef at greater depths is completely unknown.

#### EXPLANATION OF THE PLATES.

##### PLATE 35.

- Fig. 1. A moderate surf on the barrier edge opposite Taunoa. The upthrow of the wave is about 8 feet. The edge is high at this point and falls abruptly to the lagoon.
2. The north coast of Rarotonga, looking west across the mouth of Avatiu inlet, showing (1) the central volcanic mountains, (2) ending in a steeper slope (possibly ancient sea cliffs) above (3) the maritime flat; (4) the coral boulder beach above (5) the narrow fringing reef; (6) the steamer anchorage outside the reef.

##### PLATE 36.

- Fig. 3. The "barrier" edge off Papeete. It is here of normal height and the surface is living. Retreat of wave has laid bare the nodular outer slope of lithothamnium plus corals, the *Sargassum* area to left is under water; the man in the canoe is holding it against the current.
4. North end of Papeete Barrier, near Taunoa Pass. The reef is high, and fall to lagoon abrupt.

Fig. 5. Rarotonga approaching from west in early morning. The maritime flat is seen surrounding the central volcanic mountains, and on the north side (to the right) steep slopes, which are possibly ancient, now degraded, sea cliffs, shown also in fig. 2 of Pl. 35. (Photograph by Mrs. Sullivan.)

#### PLATE 37.

- Fig. 6. The (western) calcrete reef of Arue, showing dykes standing up in three squares, etc. (Compare the diagram, fig. 9 in text.)
7. The high reef of Atiue, west coast of Tahiti. Dyke ridges hold up shallow pools, descending in steps to the lagoon; the last and highest step from reef to lagoon is seen on the right.
8. The upthrown block of reef rock, about 8 feet high, from the Atiue Pass, one of the very few on the circumference of the Tahitian reefs.
9. A fissure in the edge of the shore-reef north of Punaruu Gap. It is bordered by a shelf of *Lithothamnionæ* and corals on either side, but it can be seen that the trench extends back into calcrete rock, where such growths are, and always have been, impossible.
10. A circumferential basaltic dyke, such as are common in Tahitian valleys. This example is in Papetoai Bay, Moorea.

#### PLATE 38.

- Fig. 11. A dyke crossing the reef just north of Panaruu Gap, west coast of Tahiti.
12. The eastern half of the north coast of Moorea (Cook's Bay opens under the middle arrow). The three arrows indicate the summits of the old cliffs, now degraded to slopes, and of decreasing height eastwards. This is exaggerated by the perspective of the photograph.
13. The outline of the island of Moorea. In the foreground is the *Porolithon* flat of Atiue Pass. (The man in the canoe is watching a shoal of pelagic fish.)
14. Part of the large reef dyke in Papetoai Fjord. The outlying rocks in the middle distance are masses of *Porolithon* growing on the lowered reef surface. The mountains behind are the south wall of the crater valley, that on the left is Rotui, a remnant of the north wall.

#### PLATE 39.

- Fig. 15. The raised coral flat at Temae, Moorea. Its undercut edge is seen on the right, and over its surface are hummocks, the remains of *Porites* colonies still in the position in which they grew.
13. The gap between the Tiahura Islets, Moorea. In the background the band of "raised" coral extends between two islets; within this are loose blocks of *Porites* resting upon unconsolidated rock. The bushes on the coral rock-band are *Pemphis*.
17. Temae Islet, looking east, the smooth outline of Tahiti in distance. Beach of broken coral with beach rock at its base. The reef is here "fringing."
18. The high cliffs of the west end of the north coast of Moorea, looking west from near Papetoai, seen across a bay of red mud flats.

Biological Races in *Hyponomeuta padella* L. By W. H. THORPE, B.A.,  
Research Fellow, International Education Board. (From the Zoo-  
logical Laboratory, Cambridge. Communicated by Prof. J. STANLEY  
GARDINER, F.R.S., F.L.S.)

[Read 19th April, 1928.]

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#### INTRODUCTION.

Experiments on the small Ermine Moths of apple and hawthorn were begun three years ago with the object of investigating the remarkable variations in colour and life-history occurring in this species. There seemed to be three possible ways of regarding these different forms:—(a) that there were two distinct species concerned; (b) that the differences were indications of the existence, within the one species, of two or more biological races adapted to different food-plants; or (c) that *H. padella* was merely a very variable polyphagous species, the different forms of which had no constancy or biological significance.

The work is of necessity slow, owing to the fact that the species is univoltine, but nevertheless interesting and suggestive results have already been obtained with regard to certain aspects of the problem. Owing to absence in U.S.A., the writer will not be able to carry on the breeding in the present year, but A. P. G. Michelmores has undertaken to do this, so that it is hoped to obtain further results, particularly dealing with genetics and with the behaviour of the hybrids.

Mr. J. C. F. Fryer originally suggested the work, and I should like here to express my sincere thanks to him and to Prof. J. Stanley Gardiner for



their interest and for valuable suggestions. My thanks are also due to Dr. Hugh Scott for providing material for the study of the genitalia from the collections in the Cambridge University Museum, and also to Dr. A. Busck, of the U.S. National Museum, for enabling me to examine the material under his care. I have also to thank Mr. W. H. Tams, of the British Museum, for help with the involved synonymy of the genus. I am indebted to many for sending living specimens from various parts of the country. More especially I would mention Mr. A. Roebuck, of the Midland Agricultural College, Sutton Bonnington; Mr. Robert Adkin, and Dr. R. C. L. Perkins, F.R.S. Lastly, Mr. L. Eastham has kindly undertaken to see this paper through the press.

#### SYSTEMATIC.

There are seven British species of the genus *Hyponomeuta*. Of these *H. padella* L. and *H. euonymella* L. (*H. padi* Zell.) feed chiefly on plants of the Rosaceæ; three species *H. cognatella* Hübn. (*H. euonymella* Scop., *H. euonymi* Zell.), *H. irrorella* Hübn., and *H. plumbella* Schiff. are found on *Euonymus*; while *H. vigintipunctata* Retz. and *H. stanellus* Thunb., a recent addition to the British list, occur on plants of the genus *Sedum* \*.

Five of these species are readily distinguishable on their wing-characters alone, which are fairly constant. The two remaining ones, *H. padella* and *H. cognatella*, are very close to each other, the typical white form of *H. padella* only differing from *H. cognatella* by the grey rather than white cilia of the fore wing and by the rather larger size. Some exceptionally pure white *padella*, with white fringes, that I reared from larvæ taken from crab apple (*Pyrus malus*) and from cultivated apples, are distinguishable from *cognatella* only with very great difficulty. *H. cognatella* is a very constant species showing very little colour-variation, but *H. padella* varies very greatly in the amount of grey present on the fore wings, some insects being almost pure white, while others are a uniform dark leaden grey, almost every gradation between the two being found. These colour-forms have at various times been given specific rank, the more important synonyms being as follows:—

*Hyponomeuta padella* Linn. Syst. Nat. p. 535 (1758).

*Hyponomeuta variabilis* Zell. Isis. p. 214 (1844).

*Hyponomeuta malivorella* Guen. Ann. Soc. Ent. France, p. 342 (1845).

*Hyponomeuta malinella*, Zell. Isis, p. 220 (1844).

The name *padella* was originally applied to the insects which have the fringes of the fore wings grey in colour, the name *variabilis* and other synonyms being applied to different varieties of this type according to the

\* This synonymy is that established and recognised by Meyrick (7), and Standinger and Rebel (11).

size, and to the extent and depth of the grey coloration. The name *malinella* was used for the pure white form with white cilia. These are now, however, usually considered as comprising one species only, as the different forms merge into each other by imperceptible gradations\*.

#### OUTLINE OF LIFE-HISTORY OF *H. PADELLA*.

The imagines of *padella* are on the wing from about the second week in July till towards the end of August. The adults of *cognatella* have been observed feeding ravenously on the honey-dew of *Aphis rumicis* (11) and probably a similar habit exists in other species. Eggs are laid in batches of varying size, the average number being about 30–35. Each egg is closely cemented to the next, so that a single scale-like structure is formed. The eggs hatch in late September, but the larvæ remain under the egg-scales till the following spring, when they commence boring into the buds, later mining into the leaves and skeletonizing them. In May the colonies of larvæ become more conspicuous, feeding in compact masses. They now devour the leaves, which they draw together and cover with a thick web of silk. Pupation takes place at the end of June and early in July.

The most usual food-plants of *padella* are hawthorn (*C. oxycanthus*), apple (crab, *Pyrus malus*, and cultivated varieties), and blackthorn (*Prunus spinosa*). Less commonly recorded are cultivated plums, cherry, pear, and sporadically mountain-ash (*Sorbus aucuparia*) and other plants are attacked. The insect is a defoliating pest of importance in this country, being most serious in apple orchards. Severe attacks on cherry have been recorded from U.S.A., where the insect has been introduced, but no very heavy infestations of cherry appear to have been recorded from this country.

It has long been observed that the different colour-forms appear to have some correlation with the food-plant. Thus among moths reared from larvæ feeding on apple and crab apple, the form with pure white fore wings is usually greatly in excess (rather over 90 per cent.), while among those from hawthorn the pure white insect is comparatively seldom found, the greater proportion being suffused with grey, while a small number are of a uniform dark leaden grey. Mr. J. C. F. Fryer, who has kindly put at my disposal some notes made during a big epidemic outbreak in the Midlands in 1913, found a high proportion (80 per cent.) of dark grey forms among the hawthorn *padella*, the remaining 20 per cent. being intermediate between white and grey. Insects reared from blackthorn are also of this type, but in the writer's experience the very dark form is rather more prevalent, and white

\* It is possible that the insect referred to here as the apple form of *padella* is not absolutely identical with that originally described as *malinella*. If this is the case, the only effect is to give added strength to our argument for regarding the forms dealt with as constituting but one species.

insects are rare. The insects concerned in the outbreaks on plum seem to be to some extent intermediate in coloration between the apple and hawthorn feeders, although on the whole much nearer the latter. Mr. Fryer tells me that in 1913 the most characteristic feature of the plum-feeder was the number of individuals of grey and white coloration, with relatively few pure white or pure grey.

In addition, there are one or two interesting biological differences between the apple and hawthorn forms. The cocoons of the apple-fed larvæ are generally composed of a rather dense white silk resembling that of *H. cognatella* and the pupæ are usually placed together in neatly arranged rows or packets. The hawthorn and blackthorn larvæ, on the other hand, as a rule, spin only very flimsy silken cocoons, through which the pupæ can be easily seen, and these are very frequently scattered at random in the web, close packets being the exception. As a general rule, it may be said that the eggs of the hawthorn form are usually laid on the spines of the food-plant and less frequently on the main stem, while those of the apple form are placed frequently on the main stem rather than on the spurs. When the apple form is induced to oviposit on hawthorn this difference still seems to hold good, the eggs being laid on the main stem more often than on the spines. Again, the leaf-mining habit does not seem to be developed with the hawthorn-feeder, nor were Rabaté and Bernès (9) able to observe a mine with the plum-feeder. Hering (3) gives a full description of a mine in apple leaves, caused by an insect which he apparently regards as *H. padella*, as distinct from *malinella*, although his reason for this decision is not clear. It seems probable, therefore, that this difference depends upon the thickness and structure of the leaf, and does not constitute a definite biological difference between the two races.

These differences suggest that, if we are dealing with a single species, it is probable that there are two or more fairly well-marked biological races, and it was with a view to testing this that the present work was undertaken. At the same time a careful morphological study of the two forms, in all their stages, was made in order to test the conclusions of Parrot and Schoene (8) and others that we are really dealing with one morphological species.

#### REASONS FOR CONSIDERING THE VARIOUS FORMS AS CONSTITUTING A SINGLE SPECIES.

It may be said that the majority of Lepidopterists now consider *variabilis* and *malinella* to be synonyms of *padella* on the ground that all varieties of colour occur and the two forms merge into each other by imperceptible degrees. Parrot and Schoene in 1912 made an examination of both larval and adult characters in the forms from apple and cherry that occur in the United States. With regard to the larvæ, they state that they were unable

to find any tangible structural differences, nor did the genitalia of the adults give any better results. These writers also give an exhaustive review of the literature dealing with the genus, which serves to confirm their conclusions as to the identity of *padella* and *malinella*.

Another strong argument in favour of regarding the two as one species is the fact that, as mentioned above, we so frequently get them occurring together in the same locality in epidemic form and on the same individual host-plant.

Owing to the importance to this investigation of being quite positive of the absence of structural difference, the morphology was again carefully investigated, taking as a standard of comparison the closely-allied species *H. cognatella*, with the idea that if any constant structural difference could be found between *padella* and *cognatella* some clue would be given as to the systematic importance of the different structures.

#### LARVAL MORPHOLOGY.

Careful comparison of the setation of *padella* and *cognatella* larvæ in the same instars gave no indication of any constant differences. The larvæ of *cognatella* can in all stages be distinguished without much difficulty from those of *padella* by the constant pale colour of the former species, to a lesser degree by the size and shape of the patches, and to a certain extent by the larger size, but nothing more tangible could be found.

Examination of the mouth-parts of the larvæ confirmed this. Certain differences in the shape of the mandibles and the extent of development of their teeth were more constant, but these again seemed to be characteristic of certain colonies of larvæ rather than of the species as a whole. Minute details of setation etc. on the maxillæ, labium, and labrum, and their palpi showed absolutely no constant differences. This is all the more striking in the case of the labrum, as this structure has a peculiar reticulate pattern on its upper surface, which bears long hairs; while the epipharyngeal region possesses many minute backwardly-directed setæ and three pairs of large sensillæ, thus presenting many "characters" which might show differences of systematic importance. Nor were these characters of any more value in distinguishing the two forms of *padella* from one another.

A considerable number of fresh larvæ of *cognatella* and of both *padella* forms were dissected, but this only confirmed the conclusions arrived at by a study of the external anatomy. No structural differences could be found. There is, however, a rather curious difference in the colour of the testicular follicles, those of *cognatella* being of a pale primrose-yellow, while those of both forms of *padella* are a deep pinkish-orange colour. It is perhaps suggestive that the chief character by which *cognatella* can be distinguished in both larval and adult stages is the pale colour, and that this seems to apply to all the tissues as well as to the wing-scales.

## ADULT MORPHOLOGY.

The genitalia of all the British species of *Hyponomeuta* except the newly recorded form *stanellus* (Thunb.) have been examined. It is unfortunate that in this genus the genitalia do not seem to be of great systematic value. *H. euonymella*, *H. cognatella*, and *H. padella* closely resemble one another as regards genitalia. *H. irrorella* is probably distinguishable, but it was possible to examine only one good specimen. The two remaining species *plumbella* and *vigintipunctata* are, as is not surprising, quite distinct from each other and from the other four species.

Mr. Robert Adkin, who is especially interested in this genus, pointed out to me what seemed a difference in the shape of the saccus in *cognatella* and the two forms of *padella*, which he thought might prove diagnostic. When viewed from above, it is seen that in some individuals the saccus is markedly lobed, in others slightly lobed, and in others quite straight. I had noticed this previously to Mr. Adkin's calling my attention to it, but had put it down merely to individual variation. I accordingly examined a larger number of specimens. It was found that the majority of *cognatella* certainly have the saccus markedly lobed, while there is, if anything, a slight preponderance of insects with a straight saccus among the apple and crab-apple reared *padella*. The hawthorn-reared *padella*, on the other hand, contain individuals with lobed and slightly lobed saccus in approximately equal numbers with few straight saccus forms. The character is, however, too vague and variable to be of the least use in distinguishing the two forms or, for the matter of that, the two species. Taking an average over a very large number of specimens it might have some significance, but in my experience it is of less systematic value than are the variations in wing-colour.

In view of the above results, which have confirmed those of previous workers, it seems that, judging by the usual characters of systematic importance, it is impossible to regard the apple and hawthorn forms of *padella* as separate species. With *cognatella*, on the other hand, although the systematic characters distinguishing it from *padella* are very trivial, yet they are so constant under natural conditions that it must perforce be regarded as a distinct species, albeit but slightly differentiated.

The chromosome constitution of *cognatella* and of both forms of *padella* was investigated, but no difference could be detected, the haploid number being thirty-one in each case. The method adopted was to dissect out testes from larvæ shortly before pupation or from newly-formed pupæ. Good figures were obtained by fixing in Flemming (1 hour) and sectioning at 6  $\mu$ .

So much for the structural side of the question. The biological side was hardly studied by Parrott and Schoene owing to the danger of spreading the pest in the United States and has barely been touched on by other workers.

The phenomena of biological races is now known to occur in widely different groups of insects, and it seems highly probable that it plays an

important part in the evolution of new species. A résumé of much of the work has been given by C. T. Brues (2), whose paper contains a valuable bibliography, and a short summary of the subject was recently contributed by the present writer (12).

There are four chief criteria for the existence of a biological race in a phytophagous species of insect, although it is obviously not essential that all four should hold good in every case. They are as follows:—1. That the larvæ of each form should have a well-marked preference for the food-plant of their particular race. 2. That there should be differences of habit between the two forms. 3. That the adults should have a preference for egg-laying on their own particular plant. 4. That there should be a definite tendency for like forms to mate together.

A certain amount of evidence has already been published on *padella*, with regard to the first two points. Rabaté and Bernès (9) record cases where branches of plum and apple intercross and, depending on which of the two forms is present, one fruit will have the foliage eaten while the other will be immune. With regard to the first point, Parrott and Schoene state that it was with difficulty that they induced the apple form to feed on cherry, and even when forced they fed but little, and ravenously returned to apple when given the opportunity. The differences in the mode of pupation, and in the thickness of the silk composing the cocoons, have already been alluded to.

#### METHODS.

Larvæ of *H. padella* were obtained from various localities around Cambridge, derelict fields where scrubby hawthorn and blackthorn bushes had been allowed to spring up being the most favourable collecting-grounds. A certain number of the apple larvæ were obtained from gardens and orchards in the neighbourhood of Cambridge and at Wisbech, but greater numbers were taken in the Midlands, especially from Leicestershire, Nottinghamshire, and Rutlandshire, where the insect is more abundant. *H. cognatella* was obtained from *Euonymus japonicus* in Cambridge, where it is extraordinarily abundant.

The larvæ were reared in glass and muslin breeding-cages, and also to a large extent in muslin sleeves on living trees. The chief egg-laying experiments were carried out in cages of about 12 cubic feet capacity, with one side and the top of glass and the remaining sides of coarse muslin. Contrary to expectations, it was found that the egg-laying responses were very little affected by environmental conditions and that the females would behave normally in quite small cages. For oviposition, sprays of the various food-plants were placed in the cages, these being renewed at intervals throughout the experiments and a record kept of the number of eggs laid on each species of plant. Shortly before time for emergence large numbers of pupæ were carefully cut apart from their packets and placed separately in

chip-boxes, so that a supply of virgin females was ensured for the breeding experiments. Others were removed from the breeding-cages as soon as they emerged and isolated in chip-boxes till required. The mating was carried out by placing the two individuals in sleeves on living trees in the open. Living plants were always used for those eggs which it was desired to bring to maturity, as eggs laid on twigs, which latter are allowed to die, do not appear to survive.

#### FEEDING-HABITS OF LARVÆ.

As was expected it was found that larvæ taken from apple, in second and third instars, feed on that plant only, even where fresh hawthorn was intimately mingled with it. If they were given hawthorn only, they ceased to feed and started to wander about the cage. After a day or two they would commence eating the hawthorn and quickly regain their usual compact social formation. Having induced them to feed on hawthorn, it was not at first easy to get them to return to their original food. It was found that the hawthorn larvæ behaved in a similar way, only feeding on apple-leaves when starved.

Although it was always possible to get larvæ to change their food, yet it was generally found that they did not eat nearly so much when on their new host-plant. As a result of this, and no doubt also as a result of the set-back caused by the starvation during the time when the actual change was being made, it was found that there was an unusually high percentage of casualties with larvæ treated in this way and that the resulting moths were often undersized and frequently infertile.

It was found that larvæ taken from hawthorn fed on this plant in preference to blackthorn, and *vice versâ*, although once the change was made there seemed to be no further distaste for the new food. There was evidence from field-observation that larvæ would not feed indiscriminately on both hawthorn and blackthorn. In a field near St. Ives, where much of my material was obtained, there were many small hawthorn and blackthorn bushes closely intermingled with each other. In two cases where an attacked branch of hawthorn actually interlaced with blackthorn, although the insects had spun their webbing over the latter's leaves, yet these were only just nibbled, whereas the hawthorn was eaten extensively; this in spite of the fact that there were many badly infested blackthorn-bushes in the field.

Several attempts were made to rear *cognatella* larvæ on hawthorn, and *padella* on *Euonymus*. In one case a nest of hawthorn *padella* was transferred to *Euonymus*, and a small number of undersized moths emerged, but apart from this none of the attempts succeeded, even though living plants were used for the experiments, and first instar as well as later-stage larvæ used.

TABLE I.

Table showing the approximate number of eggs laid by *H. padella* (Hawthorn form) on the food-plants.

*Oviposition of H. padella. Hawthorn form.*

	<i>Hawthorn and Blackthorn</i>		<i>Apple.</i>		<i>Total.</i>	
	No. of batches.	No. of eggs.	No. of batches.	No. of eggs.	Batches.	Eggs.
Expt. 1 .	11	476	6	192	17	668
„ 2 .	4	86	0	0	4	86
„ 3 .	11	349	1	45	12	394
Total . .	26	911 =79·3 %	7	237 =20·7 %	33	1148

Average number of eggs per batch on :—

Hawthorn etc. .... 35·0

Apple ..... 33·9

TABLE II.

Table showing the approximate number of eggs laid by *H. padella* (Apple form) on the two food-plants.

*Oviposition of H. padella. Apple form.*

	<i>Hawthorn and Blackthorn.</i>		<i>Apple.</i>		<i>Total.</i>	
	No. of batches	No. of eggs.	No. of batches.	No. of eggs.	Batches.	Eggs.
Expt. 1 ..	7	232	19	550	26	782
„ 2 ..	1	60	26	1520	27	1580
„ 3 ..	0	0	7	315	7	315
„ 4 ..	1	45	30	878	31	923
„ 5 ..	1	30	5	132	6	162
Total ....	10	367 =9·75 %	87	3395 =90·25 %	97	3762

Average number of eggs per batch on :—

Hawthorn etc. .... 36·7

Apple ..... 39·0



## OVIPOSITION EXPERIMENTS.

Table I. gives the results of three experiments on the oviposition responses of the hawthorn form of *padella* carried out over two years. Larvæ taken from hawthorn and blackthorn were reared in large numbers in cages on their normal food-plant. As the moths emerged they were placed in cages containing large branches of hawthorn, blackthorn, and apple, the quantity of the first two plants together being practically equal to that of the apple, the latter if anything being rather in excess. As the branches withered they were removed, the eggs counted, and fresh sprays inserted, so that the foliage was kept fresh throughout the duration of the experiment. Although even in large cages the conditions are certainly artificial, yet the oviposition reactions do not seem easily upset, and, although the figures given for eggs are approximations only, owing to the large numbers involved, the differences are fully significant.

Table II. gives the results of five similar experiments with the apple form, in which the numbers dealt with were greater and the results even more striking.

These experiments strongly indicate that there are definite apple and hawthorn races of *padella*.

Plum, cherry, and damson plum were also included in some of the cages containing the apple form *padella*. They were not, however, used for oviposition, save for a single batch of forty-five eggs laid on damson. In two other experiments the moths were given a choice of *Euonymus japonica*, *E. europæus*, and apple, but, as was expected, the *Euonymus* was never used by the apple form, nor was it possible to induce *H. cognatella* to oviposit on apple unless no other alternative was provided.

There is, of course, the possibility that this choice of one plant for oviposition on the part of the female may be merely a case of memory of the taste of the food on which the insect fed when it was a larva and have nothing to do with hereditary constitution. It has been suggested, for instance, that the provisioning instincts of the hunting wasps might be accounted for in this way. Accordingly, experiments were undertaken to test this. Larvæ of each form of *padella* were reared on the food-plant of the other, and the resulting moths given the usual choice for oviposition. Owing to the rather high rate of mortality among larvæ treated in this way, and also to the fact that larvæ that have received a serious set-back often produce undersized and abnormal moths, it has unfortunately not yet been possible to carry out experiments on a sufficiently large scale for the results to be altogether conclusive. It does, however, seem safe to state that the egg-laying responses are certainly not the result of larval memory only, and that change of food-plant in one generation is not sufficient to alter the oviposition instincts to any great extent.

This part of the work is being continued in order to see if food-plant change over two or three generations will have a more marked effect. The figures so far obtained are as follows :—

TABLE III.

*Hawthorn form padella reared on Apple.*

## Results of two experiments.

Hawthorn .....	19 batches.	708 eggs.	100 per cent.
Apple .....	nil.	nil.	

*Apple form padella reared on Hawthorn.*

## One experiment.

Hawthorn .....	11 batches.	280 eggs.	30·8 per cent.
Apple .....	26 batches.	630 eggs.	69·2 per cent.

As mentioned above, temporary starvation is required to induce larvae from blackthorn to commence feeding on hawthorn and *vice versa*. It seems not unreasonable to suppose, therefore, that the hawthorn form of *padella* may itself be differentiated into subsidiary biological races of blackthorn and hawthorn forms less sharply differentiated than those we have hitherto been discussing. In order to come to a definite conclusion on this point, it would probably be necessary to conduct experiments on a larger scale and in bigger cages than has hitherto been attempted, in order to ensure that conditions should be as natural as possible. Nevertheless, the figures already obtained seem worth quoting.

For experimental purposes moths were obtained from blackthorn. In one case young larvae were taken and reared on blackthorn in cages. In a second case the insects were collected from blackthorn as pupæ, so that they had fed all their lives on this food-plant under natural conditions—consequently any effects due to artificial conditions of rearing were eliminated. Insects so obtained were given the choice of blackthorn and hawthorn for oviposition. Out of a total of 550 eggs laid, 58·4 per cent. were on blackthorn and 41·6 on hawthorn. The average number of eggs per batch being 45·7 in the first case and 28·5 in the second.

Hawthorn-reared insects given a similar choice laid 825 eggs, there being 18·8 per cent. on blackthorn and 81·2 per cent. on hawthorn, the average size of the batches being 31·0 and 39·4 respectively. The figures in the case of the hawthorn insects must be used with caution, as these results were extracted from the experiments which are summarized in Table I., and as in these hawthorn was often considerably in excess of the quantity of blackthorn, the figure 81·2 per cent. is probably unduly high. Owing to this, and to the fact that with the blackthorn form the difference between the number of eggs on the two plants is comparatively small, these results

must not be taken as conclusive. They do suggest, however, that the blackthorn-feeders are slightly differentiated, and perhaps the plum form, which I have not been able to obtain for experiment, may be accounted for in the same way.

As *H. cognatella* is excessively abundant in Cambridge on *Euonymus japonicus*, a similar attempt was made to ascertain whether there were also separate biological races of this species adapted to *E. europæus* and *E. japonicus*, but this enquiry has so far yielded negative results.

#### MATING PREFERENCES.

In order to test the mating preferences of the two forms, experiments were carried out in the following way:—Equal numbers of typical males and females of each race were placed together in a breeding-cage. The insects quickly become “rubbed,” with the result that the two forms soon get quite indistinguishable; consequently it was necessary to mark all the individuals of one race in some way. A drop of red ink placed on the thorax and wings with a fine brush proved quite satisfactory and did not easily become obliterated. In this way when a pairing took place it could be seen at a glance whether it was a cross between the two forms or a like mating. Coition takes place chiefly at night and generally lasts for about 12 hours or a little under, although sometimes enduring for as much as 24 hours or even longer. The experiments were carried on for from 8 to 10 days, each cage being inspected at intervals throughout the day during this period and the number of matings recorded. The results show a strong mating preference between like forms. A summary of three experiments gives the following figures:—of 28 pairings 19 were like matings, and 9 were crosses between the two races. That is to say, the attraction between like forms is roughly twice as strong as between unlike forms. In order to avoid any possible source of error, care was taken that the individuals used in each experiment were from more than one colony, so that the results obtained could not be affected by any disinclination for inbreeding.

The methods adopted in producing cross-matings have already been described. For present purposes, it is important to note that fertile eggs are produced readily as a result of mating of the two races. It should, however, be mentioned that the number of infertile pairings is slightly higher in “crosses” (over 30 per cent.) than in the matings between like forms (under 20 per cent.), and the average number of eggs per mating is somewhat lower, being 33 in the first case and slightly over 40 in the second. The  $F_1$  individuals also mate freely, and the resulting eggs do not show any very marked diminution in fertility. This is, of course, another argument in favour of regarding the two as constituting one species.

Similar crossing experiments between *cognatella* and *padella* are in progress, but, although mating takes place fairly readily, 8 crosses 20 like matings (total of four experiments, 28 matings), there has been greater difficulty in obtaining living eggs.

#### DISCUSSION.

It will be seen from the above results that on all four counts the evidence for regarding the hawthorn and apple forms as distinct biological races is very strong.

The attachment of these races to certain plants suggests that the difference in food has been the direct cause of their production. It seems possible that further divergence will in time be brought about by means of the isolating effect of the feeding-habits and the mating-preferences, and that eventually distinct species will result. Dr. M. Hering (4) has stated as a general law that in the Lepidoptera the polyphagous forms are phylogenetically the oldest, monophagy being a more recently evolved habit. If this is so, then it seems natural to suppose that monophagous races are of comparatively recent origin and will in time be differentiated into true monophagous species. It may be that we are concerned with another case of induced mutation, comparable to that produced by Heslop Harrison (5, 6) in certain moths and in the Tenthredinid *Pontania*, but this at present is entirely speculation. Nevertheless, the hypothesis that in these forms we are really dealing with species in the making is attractive.

#### ECONOMIC IMPORTANCE.

From the point of view of the grower wishing to clear his orchard of the pest, it is important to know whether it is necessary to treat any surrounding hawthorn hedges that may be infested. Although there is an interesting record of infestation of apples (Bos., see ref. 7) from hawthorn, yet from what we know it seems unlikely that this occurs frequently under normal conditions, and accordingly the treatment of hawthorn hedges would not be a sound investment. A severe attack of the hawthorn form on hedges in the neighbourhood of an orchard should, however, serve to put a grower on his guard and enable him to deal effectively with the early stages of an apple attack should it occur. If both hawthorn and apple should be badly attacked, it might even be a definite advantage to leave the hawthorn form and thereby keep up the supply of parasites ready to attack any apple infestation that might occur. It is well known that the genus is subject to the attacks of a variety of parasites which are not confined to one-host species, and it has been suggested by Reuter that an attempt should be made to control *padella* (*malinella*) in Finland by collecting and breeding parasitised cocoons of *H. cognatella*.

## SUMMARY.

1. The life-history of *Hyponomeuta padella* is briefly described.
2. Structural investigations of larvæ and adults confirm previous statements that the Hawthorn and Apple forms of *H. padella* are not distinct species.
3. The chief criteria establishing the existence of a biological race are outlined.
4. Investigations dealing with the food-requirements of the larvæ, the oviposition and mating preference of the adults, and the chromosome constitution of the different forms are described.
5. The results of breeding experiments constitute strong arguments in favour of regarding apple and hawthorn forms of *H. padella* as two biological races of one species.
6. The economic aspect of the question is briefly discussed.

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(A complete Bibliography of the genus *Hyponomeuta* will be found attached to the paper by Parrott and Schoene.)

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\* Known to the author in abstract only.

On some Recent Crinoids in the Collection of the British Museum.

By AUSTIN H. CLARK. (Communicated by Mr. C. C. A. MONRO, B.A., F.L.S.)

(PLATES 40-44.)

[Read 15th November, 1928.]

THE British Museum, through Mr. C. C. A. Monro, has recently done me the honour of submitting to me for study an unusually interesting collection of recent Crinoids assembled from various sources.

The collection includes fifty-five species, nine of which are new and are here described. No fewer than twenty-eight species, including all of the new forms, were secured by the cable-repair ships of the Eastern and Associated Telegraph Company in the Malayan region, among the Lesser Sunda Islands and the Seychelles, off the east Coast of Africa, and in the West Indies. The ships which are specifically mentioned on the labels are the 'Cable,' the 'Patrol,' the 'Lady Denison-Pender,' the 'Recorder,' and the 'Norseman.'

There could be no better demonstration of the value of the contributions made by cable-repair ships to the study of the bottom life of the deeper portions of the sea, and the officials of the company and the commanders and officers of the ships are to be commended for their work in saving this material.

The collection also includes five species collected by Professor J. Stanley Gardiner in the Maldives and at Cargados Carajos, and two collected by Dr. Cyril Crossland at Zanzibar.

Among the new species there is one which represents a new generic type to which the name *Iconometra* is given.

The nine new species herein described are the following:—

<i>Iconometra speciosa.</i>	<i>Crotalometra eridanella.</i>
<i>Stenometra diplax.</i>	<i>Perissometra occidentalis.</i>
<i>Parametra ajax.</i>	<i>Iridometra maxima.</i>
<i>Thalassometra peripolos.</i>	<i>Sarametra nicobarica.</i>
<i>Tonrometra multicirra.</i>	

Since a detailed account of the Comatulids of the East Indian region, with more or less extended notices of those of the rest of the world, was given in the memoir on "The Unstalked Crinoids of the 'Siboga' Expedition," published in 1918, it has not seemed necessary to include detailed synonymies here.

I wish to express to the authorities of the British Museum, and in particular to Mr. Monro, my deep appreciation of the privilege of examining this collection.

For the photographs of the new and heretofore unfigured species I am indebted to Dr. A. J. Olmsted of the United States National Museum.

### Family COMASTERIDÆ.

#### Subfamily CAPILLASTERINÆ.

##### COMATELLA STELLIGERA (P. H. Carpenter).

*Actinometra stelligera* P. H. Carpenter, 1880, Journ. Linn. Soc. (Zool.), xv. 198, pl. 12. fig. 26; 'Challenger' Reports, 1888, Zoology, xxvi, part 60, p. 308, pl. 5, figs. 5 a-d; pl. 58, figs. 1-2.

*Locality*.—Sahul Bank, north-western Australia; C.S. 'Recorder,' Eastern and Associated Telegraph Company.

*Notes*.—This is a very small specimen, with 7, 7, 6, 6, 4=30 arms, and unusually large cirri.

##### CAPILLASTER SENTOSA (P. H. Carpenter).

*Actinometra sentosa* P. H. Carpenter, 'Challenger' Reports, 1888, Zoology, xxvi, part 60, p. 325, pl. 66, figs. 4-6.

*Locality*.—Off Cape Padaran, southern Annam (lat. 11° 38' N., long. 109° 41' E.), 80 fathoms, C.S. 'Patrol,' Eastern and Associated Telegraph Company, from the Cape St. James-Hong Kong cable (*R. H. Ellis*), June 4, 1927.

*Notes*.—The specimen secured here has twenty-two arms about 170 mm. long, and the longest cirri have thirty-one segments.

##### COMISSIA PECTINIFER A. H. Clark.

*Comissia pectinifer* A. H. Clark, 1911, Ann. & Mag. Nat. Hist. ser. 8, vii, 644.

*Locality*.—Flying-fish Cove, Christmas Island (*C. W. Andrews*). One young individual.

#### Subfamily COMACTINIINÆ.

##### COMATULA ROTALARIA Lamarck.

*Comatula rotalaria* Lamarck, 1816, Hist. nat. des animaux sans vertèbres, ii, 534.

*Locality*.—Baudin Island, north-western Australia, 8-15 fathoms.

*Notes*.—This is a very young specimen with the outer arms just beginning to develop. There are ten cirri. This individual is in the stage called *aruensis* by P. H. Carpenter, and later described as *etheridgei* by A. H. Clark.

##### COMATULA PECTINATA (Linné).

*Asterias pectinata* Linné, 1758, Syst. Nat. ed. x, 663 (type-specimen, but not the references cited).

*Locality*.—Baudin Island, north-western Australia, 8-15 fathoms. Four small specimens, the largest with arms about 60 mm. long.

## Subfamily COMASTERINÆ.

## COMANTHUS PARVICIRRA (J. Müller).

*Alecto parvicirra* J. Müller, 1841, Monatsber. d. k. preuss. Akad. d. Wiss. 185.

*Locality*.—Torres Straits (*Prof. J. Beete Jukes*), H.M.S. 'Fly,' 1843-47. Two specimens. There is another specimen without locality which was obtained from the Godeffroy Museum.

## Family ZYGOMETRIDÆ.

## ZYGOMETRA MICRODISCUS (Bell).

*Antedon microdiscus* Bell, 1884, Report Zool. Coll. H.M.S. 'Alert,' 163, pl. 15.

*Locality*.—Baudin Island, north-western Australia, 8-15 fathoms. Two small specimens.

## ZYGOMETRA COMATA A. H. Clark. (Pl. 44. fig. 15.)

*Zygometa comata* A. H. Clark, 1911, The Recent Crinoids of Australia, 762, footnote.

*Localities*.—Eighty miles north-west of Penang, 40 fathoms, cable-ship 'Patrol,' Eastern and Associated Telegraph Co., through Colonel Grant, I.M.S. Taken in May 1923 from a cable laid two years previously.

Singapore, 7 fathoms, December 12, 1898.

*Notes*.—One of the two specimens collected by the 'Patrol' has thirty arms 90 mm. long. Of the ten II Br series present nine are 4(3+4) and one is 2. Two of the III Br series are 4(3+4)—these are situated side by side on the II Br 4(3+4) series, which is paired with the II Br 2 series. There is a single IV Br 4(3+4) series on the innermost branch (nearest the mid-radial line) from a III Br 2 series. The division series are in close lateral contact. The longest cirri have 29-35 segments. The transition segment, which is not strongly marked, is usually the seventh or eighth. The colour is brownish-yellow with narrow and widely spaced cross-bands on the arms (Pl. 44. fig. 15).

The other specimen collected by the 'Patrol' has fourteen arms 110 mm. long. All four of the II Br series are 4(3+4). The cirri are XXI, 33-40, 35 mm. in length. The colour is light greyish, the arms with narrow and widely spaced deep purple cross-bands.

The specimen from Singapore is small, with twenty arms.

## CATOPTOMETRA MAGNIFICA A. H. Clark.

*Catoptometra magnifica* A. H. Clark, 1908, Smithsonian Miscell. Coll. (Quarterly Issue), lii, part ii, 208.

*Localities*.—Off Cape Padaran, southern Annam (lat. 11° 38' N., long. 109° 41' E.), 80 fathoms, C.S. 'Patrol,' East and Associated Telegraph Company, from the Cape St. James-Hong Kong cable (*R. H. Ellis*), June 4, 1927.



Rotti Strait, 100 fathoms, C.S. 'Cable,' Eastern and Associated Telegraph Company, from the Banjuwangi-Darwin No. 2 cable.

*Notes.*—The specimen from off southern Annam is a slender example with about twenty arms, which are about 130 mm. long. The longest cirri have twenty-two to twenty-three segments. The two youngest cirri, at the periphery of the centro-dorsal, differ from the others in lacking the strongly produced and everted distal ends of the segments, which gives them quite a distinctive aspect; they are also not so strongly curved as are the other cirri.

The larger of the two specimens from Rotti Strait is rather small and slender, with about thirty arms which are about 130 mm. long; the arms are arranged in 2, 1, 1, 2 order.

The other specimen from Rotti Strait is very small and much broken. It is apparently undergoing adolescent autotomy.

#### Family HIMEROMETRIDÆ.

##### HETEROMETRA CRENULATA (P. H. Carpenter).

*Antedon crenulata* P. H. Carpenter, 1882, Journ. Linn. Soc. (Zool.), xvi, 507.

*Locality.*—Baudin Island, north-western Australia, 8-15 fathoms. One small specimen.

##### HETEROMETRA REYNAUDII (J. Müller).

*Comatula (Alecto) reynaudii* J. Müller, 1846, Monatsber. d. k. preuss. Akad. d. Wiss. 178.

*Locality.*—South Male, Maldive Islands (*Prof. J. Stanley Gardiner*). Two small ten-armed individuals.

##### HETEROMETRA ASPERA A. H. Clark.

*Heterometra aspera* A. H. Clark, 1909, Vidensk. Medd. fra den naturhist. Foren. i. København, 102.

*Locality.*—Singapore, 7 fathoms, December 12, 1898. Two specimens.

##### HETEROMETRA SINGULARIS A. H. Clark.

*Heterometra singularis* A. H. Clark, 1909, Proc. U.S. Nat. Mus. xxxvi, 658.

*Locality.*—Eighty miles north-west of Penang, 40 fathoms, cable-ship 'Patrol,' Eastern and Associated Telegraph Co., through Col. Grant, I.M.S. Taken in May 1923 from a cable laid two years previously.

*Notes.*—Although the six specimens collected at this locality are much larger and better developed than the type-specimen of *H. singularis*, there can be no doubt that they represent the same species. One of them may be described as follows:—

The centro-dorsal is discoidal, moderately thick, with the bare dorsal pole flat, though with an irregular surface, 4 mm. in diameter. The cirrus-sockets are arranged in two alternating marginal rows.

The cirri are XXII, 37-39, about 35 mm. long. The first segment is short, and those following gradually increase in length to the fifth or seventh, which is about as long as broad. In the longest cirri the next ten segments are subequal, somewhat longer than broad, and those succeeding slowly decrease in length so that the distal are broader than long, though never much so. On a segment between the fifteenth and the nineteenth a sub-terminal dorsal tubercle appears, which, two segments beyond, becomes a conspicuous dorsal spine and, in lateral view, appears as a narrow triangle with the sharp apex terminal, arising from the entire dorsal surface of the segment and in height equal to about one-third the width of the segment.

The distal edge of the radials is just visible beyond the rim of the centro-dorsal; it usually bears a single row of small and regular bead-like tubercles, but may be simply roughened. The division series are broad, in close lateral contact, and laterally flattened. The lateral borders of the elements of the division series are slightly produced, the production forming a narrow margin with a straight outer edge. Of the eight II Br series, six are 4(3+4) and two are 2. The two III Br series, which are both developed on the same I Br series, are 2.

The twenty arms are 150 mm. long. The earlier brachials are wedge-shaped, short, twice as broad as the maximum length; beyond the proximal third of the arm the brachials become almost oblong and about four times as broad as the median length.

$P_D$  is 10 mm. long, and is composed of 32 segments. It tapers rapidly on the first nine segments, beyond which it is very slender. The first segment is much broader than long, but those succeeding gradually increase in length so that the eighth and following are about as long as they are broad. The first six segments are sharply carinate, the carination being narrow with the crest straight and parallel with the longitudinal axis of the segments. The first two or three segments are flattened against the corresponding segments of the adjacent pinnule on the neighbouring arm.

$P_1$  is about 13 mm. long, and is composed of 34 segments. It tapers rather rapidly in the first eight segments, becoming slender and flagellate distally. The segments become as long as broad on the third to the sixth, then longer than broad, the last ten being about twice as long as broad. The first seven segments are sharply carinate, the carination being highest on the second and third, and disappearing at the distal end of the seventh.

$P_2$  is 19 mm. long, and is composed of 33 segments which become as long as broad on the fourth, and on the last ten twice as long as broad. The second to seventh segments bear a sharp knife-like carinate process, which is narrow, with a straight crest parallel to the longitudinal axis of the segments. The pinnule is only moderately stout, and tapers with extreme slowness from the base to the tip, which gives it a strap-like appearance.

$P_3$  is 13 mm. long, with 27 segments, which beyond the fifth are all about as long as broad. The second-sixth are sharply, though narrowly, carinate.

$P_4$  is 9.5 mm. long, with 23 segments, less stout at the base than  $P_3$ , tapering rather rapidly in the proximal half so that the distal half is slender and flagellate. The segments become as long as broad on the sixth and twice as long as broad terminally. The second-sixth segments are narrowly carinate.

Another specimen resembling the preceding has 15 arms, there being four II Br 4 (3+4) series and one III Br 2 series, developed internally. The longest cirri have 36-39 segments.

A third specimen has 12 arms 90 mm. long, there being two II Br 4(3+4) series. The longest cirri have 32-33 segments.

The three other specimens are more greyish in colour and slightly smoother in appearance. One has 14 arms 140 mm. long; there are three II Br 4(3+4) series and a single III Br 2 series, developed internally.

Another has 13 arms 130 mm. long; there are two II Br 4(3+4) series and one III Br 2 series internally developed.

The last example has 13 arms 100 mm. long; there are two II Br 4(3+4) series and one III Br 2 series developed internally. The longest cirri have 41-43 segments and reach a length of 35 mm.

#### AMPHIMETRA MOLLERI (A. H. Clark).

*Himerometra molleri* A. H. Clark, 1903, Proc. Biol. Soc. Washington, xxi, 222.

*Localities*.—Eighty miles north-west of Penang, 40 fathoms, cable-ship 'Patrol,' Eastern and Associated Telegraph Co., through Col. Grant, I.M.S. Taken in May 1923 from a cable laid two years previously.

Singapore, 7 fathoms, December 12, 1898.

*Notes*.—The specimen collected by the 'Patrol' has arms about 145 mm. in length. The cirrus-segments are somewhat longer than usual.

In the example from Singapore the cirrus-segments are also slightly longer than usual.

#### AMPHIMETRA ENSIFER (A. H. Clark).

*Himerometra ensifer* A. H. Clark, 1903, Proc. Biol. Soc. Washington, xxi, 225.

*Locality*.—Singapore, 7 fathoms, December 12, 1898. Seven specimens.

### Family MARIAMETRIDÆ.

#### PONTIOMETRA ANDERSONI (P. H. Carpenter).

*Antedon andersoni* P. H. Carpenter, 1889, Journ. Linn. Soc. (Zool.), xxi, 306, pl. 26, figs. 1-5; pl. 27, fig. 8.

*Locality*.—Eighty miles north-west of Penang, 40 fathoms, cable-ship 'Patrol,' Eastern and Associated Telegraph Co., through Col. Grant, I.M.S.

Taken in May 1923 from a cable laid two years previously. This species is here represented by a detached visceral mass.

**LAMPROMETRA PALMATA** (J. Müller).

*Alecto palmata* J. Müller, 1841, Archiv f. Naturgesch. i, 144.

*Localities*.—Muhlos, Maldive Islands (*Prof. J. Stanley Gardiner*); Flying-fish Cove, Christmas Island (*C. W. Andrews*); Macclesfield Bank, 10–13 and 13 fathoms.

*Notes*.—All of the specimens are small. That from the Maldives has 14 arms 60 mm. in length.

*Remarks*.—This is the species which I have previously called *Lamprometra protecta* (Lütken) (*Antedon protectus* Lütken, in P. H. Carpenter, 1879, Trans. Linn. Soc. (Zool.), ser. 2, ii, 19). It is evident from Müller's original description and from the locality he gave (India, probably the Dutch East Indies) that it was this species which he had, and not that from the Red Sea. The latter must be known as *Lamprometra klunzingeri* (Hartlaub) (*Antedon klunzingeri* Hartlaub, 1890, Nachr. Ges. Göttingen, 175).

The name *protecta* is properly applicable to the species now called *Stephanometra monacantha* (Hartlaub), 1890 (Nachr. Ges. Göttingen, 179), which, therefore, becomes *Stephanometra protecta* (Lütken).

**LAMPROMETRA GYGES** (Bell).

*Antedon gyges* Bell, 1884, Report Zool. Coll. H.M.S. 'Alert,' 160, pl. 12, figs. B, B a-b.

*Localities*.—Hermit Island, north-western Australia. One specimen; Australia, purchased from H. B. Preston. Two specimens.

? **LAMPROMETRA KLUNZINGERI** (Hartlaub).

*Antedon klunzingeri* Hartlaub, 1890, Nachr. Ges. Göttingen, 175.

*Locality*.—Zanzibar (*Dr. Cyril Crossland*). One small specimen of what appears to be this species.

**DICHROMETRA AFRA** A. H. Clark.

*Dichrometra flagellata* var. *afra* A. H. Clark, 1912, Smithsonian Miscell. Coll. ix, no. 10, p. 23.

*Locality*.—Zanzibar (*Dr. Cyril Crossland*). One small specimen.

Family COLOBOMETRIDÆ.

**CYLLOMETRA MANCA** (P. H. Carpenter).

*Antedon manca* P. H. Carpenter, 1888, 'Challenger' Reports, Zoology, xxvi, part 60, 226, pl. 44, figs. 2, 3.

*Locality*.—Rotti Strait, 100 fathoms, C.S. 'Cable,' Eastern and Associated Telegraph Co., from the Banjuwangi-Darwin No. 2 cable. Three specimens.

## DECAMETRA ALAUDÆ A. H. Clark. (Pl. 44. fig. 14.)

*Decametra alaudæ* A. H. Clark, 1911, Proc. U.S. Nat. Mus. xl, 33.

*Locality*.—Cargados Carajos (*Prof. J. Stanley Gardiner*).

*Notes*.—There are two specimens, one large and one much smaller. In the larger specimen the centro-dorsal is thin, discoidal, with the dorsal pole broad and sunken in such a way that only the outer border rises to the lower edges of the cirrus-sockets. The cirri are arranged in a fairly regular marginal row.

The cirri are XX, 26, about 12 mm. long. The segments in the proximal third of the cirri are about twice as broad as long, those succeeding becoming about half again as broad as long, and the distal being only slightly broader than long. On the third or fourth segment a ridge appears on the dorsal side, in the shape of a broad V with a rounded apex; the two ends of the V lie at the distal outer angles of the segment, and the rounded apex is just within the middle of the proximal border. Almost immediately the apex of the V disappears, so that only two short diagonal ridges are left, which, on about the twelfth segment, become reduced to a pair of small tubercles, those on the antepenultimate fusing into a single median tubercle.

The radials in the mid-radial line are even with the rim of the centro-dorsal. The I Br<sub>1</sub> are short, about four times as broad as long, with the distal border somewhat concave and the lateral edges rather broadly in contact basally, diverging from the point of contact at an angle of about 45°. The I Br<sub>2</sub> (axillaries) are almost triangular, about twice as broad as long. The short lateral edges make an angle of about 90° with those of the I Br<sub>1</sub>.

The 10 arms are about 100 mm. long. They remain of uniform width for an unusual distance, and then taper very slowly.

P<sub>1</sub> is 7 mm. long with 17 segments, of which the first is twice as broad as long, the fourth is about as long as broad, and those following are about half again as long as broad. The pinnule is rather stout basally, but tapers rapidly in the proximal third, and more gradually from that point onward; it does not become flagellate distally.

P<sub>2</sub> is 12 mm. long, much larger, stouter and stiffer than P<sub>1</sub>, with about 18 segments of which the first is half again as broad as long, the fourth is very slightly longer than broad, and those following about one-third longer than broad. From the fourth onward the segments have the distal edge abruptly and prominently everted and dentate.

P<sub>3</sub> resembles P<sub>2</sub>, but is shorter and less stout; usually the difference is only slight, though it may be considerable.

P<sub>4</sub> may be much shorter, more slender, and less stiffened than P<sub>3</sub>, resembling the succeeding pinnules, or it may be intermediate between P<sub>3</sub> and the following pinnules.

The colour is purplish brown with a narrow white band running directly across the arm in the middle of each brachial. In the proximal fourth of the arm this light transverse band on the pinnule side of the brachials suddenly expands, forming a ring about a large circular brown spot. The enlarged lower pinnules are light with a central dark dot on more or fewer of the basal segments. Some of the arms are light, with narrow brown bands along the articulations. The centro-dorsal and the cirri are uniform in colour and rather dark.

**DECAMETRA MOLLIS (A. H. Clark).**

*Cylometra mollis* A. H. Clark, 1909, Proc. Biol. Soc. Washington, xxii, 76.

*Locality*.—Muhlos, Maldive Islands (*Prof. J. Stanley Gardiner*). Four specimens.

**Iconometra, gen. nov.**

*Diagnosis*.—A genus of Colobometridæ in which  $P_1$ ,  $P_2$ , and  $P_3$  are similar, elongated, stiffened, evenly tapering, and composed of segments which beyond the first two are much elongated;  $P_2$  is longer than  $P_1$  or  $P_3$ ;  $P_4$  is present; the cirri are rather stout and are composed of 15–23 short subequal segments, none of which are longer than broad, bearing dorsally a more or less marked transverse ridge, situated at or very near the proximal end; the arms are 10–20 or more in number; the division series, which are always 2, are broad and in lateral contact except for water-pores, and the brachials are broader than long, except in the outer portion of the arms.

*Genotype*.—*Iconometra speciosa*, sp. n.

*Remarks*.—This new genus is most closely allied to *Oligometrides*, from which, however, it appears to be quite distinct. In addition to the type-species described below, it includes two others: *Iconometra anisa* (H. L. Clark), from Torres Straits, and *Iconometra bellona* (A. H. Clark), from the Philippines.

**ICONOMETRA SPECIOSA, sp. n. (Pl. 40. figs. 1, 2.)**

*Locality*.—Off Cape Padaran, southern Annam (lat.  $11^{\circ} 38' N.$ , long.  $109^{\circ} 41' E.$ ), 80 fathoms, C.S. 'Patrol,' Eastern and Associated Telegraph Co., from the Cape St. James–Hong Kong cable (*R. H. Ellis*), June 4, 1927.

*Diagnosis*.—A species of *Iconometra* in which the arms are about 20 in number and 75 mm. in length, and the cirri are XL, 20–23, 13 mm. long.

*Description*.—The centro-dorsal is hemispherical, slightly flattened, 3.5 mm. broad at the base. The dorsal pole, which is about 1 mm. broad, is studded with small scattered tubercles. The cirrus-sockets are arranged in three rows and a partial fourth row.

The cirri are about XL, 20-23, about 13 mm. long. The first segment is short, the second is twice as broad as long, and those following gradually increase in length, so that the fifth or sixth and following are very nearly as long as broad, becoming terminally quite as long as broad. The cirri of the peripheral row are all lacking. In these probably all the segments are broader than long. On the third or fourth cirrus-segment the proximal end is thickened dorsally. On the segment succeeding, this thickening rises into a transverse ridge with a very finely dentate crest, which is convex when the segment is viewed end-wise. On the following segments this crest becomes straight. Distally the crest becomes gradually shorter, but the process remains as a proximal transverse ridge as far as the antepenultimate segment. The opposing spine is prominent, higher than the transverse ridge on the preceding segment, conical or with a chisel-shaped elongated edge, median, or situated in the proximal portion of the penultimate segment, and inclined more or less proximally. The cirri are rather stout, and are of uniform width throughout.

The distal borders of the radials are just visible beyond the rim of the centro-dorsal. They are narrowly thickened, or are provided with a continuous row of fine bead-like tubercles. The I Br<sub>1</sub> are short, four or five times as broad as long, somewhat higher in the median line than laterally. The lateral borders are in contact basally, but from the point of contact the two sides of each I Br<sub>1</sub> converge strongly. The proximal borders of the I Br<sub>1</sub> are everted and slightly thickened, or are provided with a continuous row of small bead-like tubercles. The outer portions of the distal border, and the lateral borders, are slightly everted. The I Br<sub>2</sub> (axillaries) are sharply triangular, twice as broad as long. The proximal border is straight. The lateral angles are just in contact with those of their neighbours, and therefore extend beyond the truncated antero-lateral angles of the I Br<sub>1</sub>. Except in the middle of the proximal edge, the borders all round are everted. A prominent high and narrow synarthrial tubercle is present on the articulation between the elements of the I Br series. The II Br and III Br series are 2, resembling the I Br series. Only a single externally developed III Br series is present.

The arms are apparently 21 in number, about 75 mm. in length. The first brachial is wedge-shaped, twice as long exteriorly as interiorly, and between three and four times as broad as long in the median line. The outer border is produced into a narrow flange of uniform width, and the inner is in contact with that of its fellow for about the proximal half, the two sides of the adjacent segments then diverging at an angle that varies from broadly obtuse to acute. The second brachial is larger than the first, and the proximal and distal borders make a greater angle with each other so that the ossicle is almost triangular, the inner side being extremely short or quite

reduced to a point. The first syzygial pair (composed of brachials 3 + 4) is slightly longer interiorly than exteriorly, from half again to twice as broad as the median length. Toward the inner end of the distal border a sharp angle indicates the end of the fulcral ridge. The next three brachials are oblong, about three times as broad as long, with sharp angles on the distal borders indicating the ends of the fulcral ridges. After the eighth the brachials become triangular, about half again as broad as the maximum length, with the longer side slightly convex. In the outer half of the arm the brachials become very obliquely wedge-shaped, remaining broader than long, and distally elongate. In profile view the dorsal surface of the brachials in the proximal half of the arm is seen to rise gradually to the distal end, so that the distal end of the brachials is higher than the proximal end of those succeeding, though there is no overlapping. The synarthrial tubercles on the II Br and III Br series and between the first two brachials become progressively less and less marked.

$P_1$  is 11 mm. long, and is composed of 15 segments. It is slightly stiffened and tapers evenly and gradually from the base to the slender, but not flexible, tip. The first segment is slightly broader than long, or about as long as broad; the second, which is slightly trapezoidal, is from half again to nearly twice as long as the width of the distal (shorter) end, and the third is nearly three times as long as broad; those following are about four times as long as broad, becoming even longer in the distal portion of the pinnule.

$P_2$  is 11.5 mm. long with 16 segments. It resembles  $P_1$  and is scarcely stouter basally, but it tapers more gradually and therefore is slightly stouter and stiffer in the distal half.

$P_3$  is 10.5 mm. long with 15 segments, resembling  $P_2$ .

$P_4$  is 6.5 mm. long with 13 segments, and tapers more rapidly than the preceding pinnules. The first segment is twice as broad as long, the second is nearly as long as broad, the third is nearly twice as long as broad, and the fifth and following are three or four times as long as broad. The fifth or sixth and following segments have the distal edge dorsally slightly everted and armed with fine short spines.

$P_5$  is 5 mm. long with 12 segments, about as stout at the base as  $P_4$ , but tapering much more rapidly and becoming more delicate distally. It is composed of relatively shorter segments than  $P_4$ .

The colour is purple, the ossicles of the division series with central patches of yellow, and the brachials each with a terminal stripe of yellow on the pinnule-bearing side. In the outer half the arms become banded, series of purple brachials with terminal yellow marks alternating with series of yellow brachials with purple proximal marks. The lower pinnules are yellow, more or less washed with purple at and towards the ends of the segments. The centro-dorsal and the cirri are yellow.



**OLIGOMETRA SERRIPINNA** (P. H. Carpenter).

*Antedon serripinna* P. H. Carpenter, 1881, Notes from the Leyden Mus. iii, 182.

*Locality*.—Muhlos, Maldive Islands (*Prof. J. Stanley Gardiner*).

*Notes*.—Of the two specimens, one has the arms about 50 mm. long; the cirri are XVI, 15–16, 7 mm. long; P<sub>2</sub> has 12–13 segments, the processes on the ends of the segments being of average development. The other is similar, but smaller, with the arms 40 mm. long.

**OLIGOMETRA CARPENTERI** (Bell).

*Antedon carpenteri* Bell, 1884, Report Zool. Coll. H.M.S. 'Alert,' 167, pl. 10, figs. A a–c.

*Locality*.—Baudin Island, north-western Australia, 8–15 fathoms. One small specimen.

Family **TROPIOMETRIDÆ**.**TROPIOMETRA CARINATA** (Lamarck).

*Comatula carinata* Lamarck, 1816, Hist. nat. des animaux sans vertèbres, ii, 534.

*Locality*.—Durban, Natal, 1906. One specimen.

**TROPIOMETRA AUDOUINI** A. H. Clark.

*Tropiometra audouini* A. H. Clark, 1912, Proc. U.S. Nat. Mus. xliii, 401.

*Locality*.—Hurghada, Red Sea (lat. 27° 15' N., long. 35° 50' E.) (*W. H. MacFadyen*). One specimen, with the cirri XIV, 16.

**TROPIOMETRA PICTA** (Gay).

*Comatula picta* Gay, 1854, Historia física y política de Chile, viii, 429.

*Locality*.—South of Pernambuco, Brazil (lat. 9° 05' 00" S., long. 34° 58' 00" W.), 23 fathoms, C.S. 'Norseman.'

*Notes*.—One specimen, "found in the cavernous spaces of a big sponge."

Family **CALOMETRIDÆ**.**NEOMETRA ALECTO** (A. H. Clark).

*Calometra alecto* A. H. Clark, 1911, Proc. U.S. Nat. Mus. xxxix, 544.

*Locality*.—Rotti Strait, 100 fathoms, C.S. 'Cable,' Eastern and Associated Telegraph Co., from the Banjuwangi–Darwin No. 2 cable. Three much broken specimens.

**CALOMETRA DISCOIDEA** (P. H. Carpenter).

*Antedon discoidea* P. H. Carpenter, 1888, 'Challenger' Reports, Zool. xxvi, part 60, 134, pl. 10, figs. 1, 2.

*Locality*.—Rotti Strait, 100 fathoms, C.S. 'Cable,' Eastern and Associated Telegraph Co., from the Banjuwangi–Darwin No. 2 cable. One broken specimen.

## Family THALASSOMETRIDÆ.

## Subfamily PTILOMETRINÆ.

## ASTEROMETRA MIRIFICA A. H. Clark.

*Asterometra mirifica* A. H. Clark, 1909, Proc. Biol. Soc. Washington, xxii, 146.

*Locality*.—Rotti Strait, 100 fathoms, U.S. 'Cable,' Eastern and Associated Telegraph Co., from the Banjuwangi-Darwin No. 2 cable. Two specimens.

## ASTEROMETRA CRISTATA A. H. Clark.

*Asterometra cristata* A. H. Clark, 1911, Proc. U.S. Nat. Mus. xxxix, 547.

*Locality*.—Off Cape Padaran, southern Annam (lat.  $11^{\circ} 38' N.$ , long.  $109^{\circ} 41' E.$ ); 80 fathoms, U.S. 'Patrol,' Eastern and Associated Telegraph Co., from the Cape St. James-Hong Kong cable (*R. H. Ellis*), June 4, 1927.

*Notes*.—Of the three specimens one has the arms about 90 mm. long, and the longest cirri about 70 mm. long, with 83-85 segments.

## Subfamily THALASSOMETRINÆ.

## STYLOMETRA SPINIFERA (P. H. Carpenter).

*Antedon spinifera* P. H. Carpenter, 1881, Bull. Mus. Comp. Zool. ix, 158.

*Locality*.—Snapper Bank, off the south-eastern corner of Porto Rico, from a cable, Eastern and Associated Telegraph Co.

*Notes*.—The single specimen secured has 27 arms, which are about 120 mm. in length.

## STENOMETRA QUINQUECOSTATA (P. H. Carpenter).

*Antedon quinquecostata* P. H. Carpenter, 1888, 'Challenger' Reports, Zool. xxvi, part 60, 215, pl. 3, figs. 6 a-d; pl. 38, figs. 1-3.

*Locality*.—Rotti Strait, 100 fathoms, U.S. 'Cable,' Eastern and Associated Telegraph Co., from Banjuwangi-Darwin No. 2 cable.

*Notes*.—Of the two specimens, one has 19 and the other 21 arms. All of the division series are 2.

## STENOMETRA DIPLAX, sp. n. (Pl. 41. fig. 5.)

*Locality*.—Rotti Strait, 100 fathoms, U.S. 'Cable,' Eastern and Associated Telegraph Co., from the Banjuwangi-Darwin No. 2 cable.

*Diagnosis*.—A species of *Stenometra* in which the II Br series consist of four elements in two synarthrial pairs; the cirri are XX, 73-76, from 40 mm. to 45 mm. in length.

*Description*.—The centro-dorsal is thick discoidal, about twice as broad at the base as high, 3 mm. in diameter basally. The very broad dorsal pole is studded with evenly distributed rather short and pointed papillæ. The cirrus-sockets are arranged in ten regular columns of two sockets each, there being two columns in each radial area. In the interradian lines the adjacent

columns of cirrus-sockets are separated by rather high ridges, in the mid-radial lines by narrower, lower, and sharper ridges.

The cirri are XX, 73-76, from 40 mm. to 45 mm. long, very slender and delicate. The first segment is exceedingly short, and the following gradually increase in length to the fifth, which is half again as broad as long, the sixth, which is slightly longer than broad, and the seventh-twelfth, which are the longest, about one-third again as long as broad. Beyond the twelfth the segments very slowly decrease in length, so that those in the terminal third of the cirri are about twice as long as broad. Beginning somewhat before the middle of the cirri, the distal ends of the segments become slightly produced dorsally. This production of the distal edge gradually narrows, and at the same time extends proximally, so that the short distal segments bear a prominent sharp median dorsal carination, the crest of which in profile at first rises gradually from the proximal to the distal end of the segment, but later becomes strongly convex. The opposing spine is conical, blunt, slightly higher than the process on the preceding segment. The terminal claw is scarcely so long as the penultimate segment, and is stout and strongly curved. The proximal segments are carinate ventrally, and the ventral and lateral portions of the distal edge are produced, overlapping the bases of the segments succeeding. This feature gradually dies away as the segments become shorter. In lateral view the cirri taper very slightly in the basal fourth and then remain of uniform width until near the end when they taper gradually to the tip.

The ends of the basal rays are visible as minute tubercles at the upper ends of the interradi al ridges on the centro-dorsal.

The radials are extremely short, chevron-shaped, with the distal border narrowly and the lateral edges thickly everted and irregularly dentate. The I Br<sub>1</sub> are chevron-shaped, very narrow and band-like, from six to eight times as broad as long. The proximal edge bears a few scattered teeth or lobes or other irregularities, and the lateral portions of the distal edge are more or less strongly dentate. The I Br<sub>2</sub> (axillaries) are rhombic, not quite twice as broad as long; the lateral angles are just in contact with those of their neighbours, and the distal and proximal angles are similar, the latter being somewhat more rounded. The proximal half of the median line carries a rather high sharp keel, with a straight crest. Of the nine II Br series present, eight are four, the axillary in no case being united to the preceding segment by syzygy, and one is two. The division series are narrow and high, gable-like in end view, and the mid-dorsal line is occupied by a sharp and conspicuous, though not high, carination. The lateral borders of the ossicles may be sparsely denticulate, but the proximal and distal edges are unmodified. The division series are in very close apposition, and the sides of the component ossicles are sharply flattened.

Only the arm-bases are preserved. The brachials are deep and much

compressed laterally, with a low but sharp median carination, which is obscure on the earlier brachials, though becoming conspicuous as the brachials become triangular.

*Remarks.*—While the occurrence of II Br series of four elements instead of two would seem to be an important character sharply distinguishing this form from *S. quinquecostata*, I am not sure that it is not merely a variety of the latter. The two were taken together and they seem to agree in every other feature, though the present specimen is slightly smaller with somewhat more slender cirri. This would be the case, however, with any markedly aberrant form.

It is noteworthy that in the II Br series the two distal elements are never united by syzygy, which would indicate that they are not the morphological equivalent of II Br series of  $4(3+4)$ . These latter are not known to occur in *Stenometra*, or in any of the closely related genera.

The occurrence of II Br series of four ossicles with the two outer not united by syzygy is not infrequent in Comatulids in which the division series are normally two. I once described as *Cyllometra anomala* (Proc. Biol. Soc. Washington, 1908, xxi, 225) a specimen of *C. alborpurpurea* in which six of the seven II Br series present are of four elements.

*PARAMETRA AJAX*, sp. n. (Pl. 41. figs. 6, 7.)

*Locality.*—Malay Archipelago, from a cable, cable-ship 'Patrol,' Eastern and Associated Telegraph Co.

*Diagnosis.*—A species of *Parametra* in which the arms are evenly rounded dorsally (as in *fisheri*), and the brachials have the distal edge much thickened and produced, and armed with very numerous excessively fine teeth; the cirri are relatively large and stout, XX, 23–27, about one-quarter of the arm-length.

*Description.*—The centro-dorsal is thin discoidal, with the very broad dorsal pole rather deeply sunken and finely papillose. The cirrus-sockets are arranged in one row and a partial second irregular marginal row.

The cirri are XX, 23–27 (usually nearer the latter), from 20 mm. to 25 mm. in length. The first segment is short and the following gradually increase in length to the fifth or sixth, which is almost or quite as long as broad. The sixth, seventh, or eighth is a transition segment, about half again as long as broad. The outer third of the segment is almost white, and the dorsal and ventral profiles of this white portion diverge strongly, the dorsal making a greater angle with the longitudinal axis. The following segments decrease in length, after about four becoming about half again as broad as long. The distal edge of the transition segment is rather strongly produced dorsally. On the following segments this production of the distal dorsal edge takes the form of a rather high transverse ridge with the crest flattened and dentate. Distally this ridge gradually narrows and on the last

six segments before the penultimate it is transformed into a low submedian dorsal tubercle. The opposing spine is small, conical, with the apex median or subterminal in position. The terminal claw is about as long as the penultimate segment or slightly longer, rather slender, and gently and evenly curved. The cirri increase slightly in width and thickness to the fourth or fifth segment, then decrease to the end of the transition segment, after which point they remain uniform.

The ends of the basal rays are visible as prominent and rather large rounded triangular tubercles in the angles of the calyx.

The radials are wholly concealed. The I Br<sub>1</sub> are chevron-shaped, very narrow, with parallel sides, and are in close apposition. In the median line they bear a prominent sharp keel or an elongate tubercle, extending the entire length of the dorsal surface. The lateral portions of the distal border may be unmodified, or they may be extended distally over the proximal portion of the axillaries in the form of a thin broadly scalloped flange. The I Br<sub>2</sub> (axillaries) are broadly rhombic, twice as broad as long; the lateral angles are only very slightly truncated. The dorsal surface may rise to a broad rounded prominence in the centre, with its maximum height in the proximal half, or the proximal third of the median line may be occupied by a broad longitudinally elongate tubercle or a sharp median keel. The II Br series are two, resembling the I Br series, rather narrowly convex in the median line, but without central tubercles or keels.

The twenty arms were probably about 90 mm. long. They are very narrow at the base, increasing in width to about the fourteenth brachial, and thence gradually tapering distally. The first brachial varies from three times as broad as long in the median line to only half again as broad as long. In the latter case it is wedge-shaped, longer exteriorly than interiorly; in the former the proximal and distal borders are parallel as far as the mid-dorsal line, where the distal border turns anteriorly and runs diagonally outward to the outer distal angle. When very short the first brachials have a prominent elongate tubercle occupying the entire length of the median line, but usually the dorsal surface is evenly convex and swollen so that the profile is strongly convex. The inner distal angles are more or less cut away, as are the inner proximal angles of the second brachials, so that conspicuous rhombic water-pores are formed. The second brachials are from two to three times as broad as long, in shape approximately oblong. Their distal edges are slightly prominent. The first syzygial pair (composed of brachials 3+4) is very slightly longer exteriorly than interiorly, usually about half again as broad as long. The hypozygal (third brachial) is oblong, with the distal border raised above the articular line; the epizygal (fourth brachial) is wedge-shaped, longer exteriorly than interiorly, with the distal border prominent. The following eight brachials are wedge-shaped, from three to four times as broad as long in the median line, with the longer side

about half again as long as the short. r. Their distal edges are usually raised considerably above the bases of the brachials following, giving the profile of this portion of the arm a serrate appearance; they are also usually somewhat thickened and very finely dentate. The succeeding brachials become triangular, slightly broader than long, with the distal border rather strongly concave and the distal edge strongly thickened and produced, and armed with very numerous excessively fine teeth.

$P_1$  is 7 mm. long, and is composed of seventeen segments, it is moderately stout at the base, but tapers rather rapidly in the first nine segments and becomes slender from that point onward. The first two segments are about twice as broad as long, and those following gradually increase in length, becoming about as long as broad on the fifth and sixth, and somewhat more than twice as long as broad distally. The segments are sharply carinate.

$P_2$  is 9.5 mm. long, with 18 segments, not quite so stout basally as  $P_1$ , and tapering much more gradually. The segments are at first broader than long, becoming about as long as broad on the fourth, and twice as long as broad in the outer portion. The segments are sharply carinate, and in the distal half this carination is high and at the distal angle is distally produced, considerably overlapping the base of the segment succeeding.

$P_3$  is 8.5 mm. long, with 15 segments. It is about as broad basally as  $P_2$ , but tapers very gradually and evenly to the tip so that in its distal half it is twice as broad as  $P_2$ . The segments become as long as broad on the eighth, and are distally about half again as long as broad.

$P_4$  is 9 mm. long, with 16 segments, resembling  $P_3$ , but tapering still more gradually and hence broader throughout with relatively shorter segments.

On some arms  $P_1$  may be twice as broad basally as  $P_2$ , though becoming more slender in the distal half, while on others there is very little difference between them. On the other arms  $P_1$  and  $P_2$  may be relatively small, the former very slightly stouter basally than the latter, and  $P_3$  may be much longer and broader than either.

*THALASSOMETRA PERIPOLOS*, sp. n. (Pl. 40. figs. 3, 4.)

*Locality*.—South of the Nicobar Islands, 560 fathoms, cable-ship 'Patrol,' Eastern and Associated Telegraph Co.

*Diagnosis*.—A species of *Thalassometra* in which there are no long curved spines near the distal edge of the brachials; the cirri are XVII, 31–38, from one-quarter to nearly one-third of the arm-length; the arms (in the two known specimens) are 11 in number, the II Br series being 4(3–4); the dorsal surface of the division series is thickly beset with excessively fine spines, which are often grouped in irregular bundles; on the lower brachials these become more scattered in the central portion of the dorsal surface; on the triangular and succeeding brachials the entire dorsal surface is beset

with very fine spines, which become longer on the slightly produced distal border.

*Description.*—The centro-dorsal is low, flattened hemispherical, with the almost flat dorsal pole finely pitted and finely spinous. The cirrus-sockets are arranged in one and a partial second crowded marginal row, there being usually three at the margin beneath each radial.

The cirri are XVII, 31–38 (usually about 35), from 20 mm. to 25 mm. long. The first segment is very short, the second is slightly longer, the third is about two and one-half times as broad as long, the fourth is half again as broad as long, and the fifth is somewhat longer than broad. The sixth, or more rarely the seventh, is a transition segment, somewhat less than twice as long as broad, with the distal third white, in sharp contrast to the dark brownish-yellow proximal two-thirds. The following segments are similar, but less constricted centrally. The succeeding segments slowly decrease in length, so that those in the terminal fourth of the cirri are half again as broad as long. On the transition segment the distal edge dorsally is everted and slightly produced, and finely dentate. As the segments become shorter this eversion of the distal edge dorsally increases, becoming narrower and extending proximally so as to involve a triangular area on the dorsal surface. In lateral view these processes appear as prominent blunt dorsal spines, arising from almost the whole of the dorsal surface of the segments with the apex subterminal. On a few of the segments immediately preceding the penultimate, the process narrows into a small dorsal tubercle. The opposing spine is triangular, arising from the entire dorsal surface of the penultimate segment, with the apex submedian to subterminal; its height is equal to about one-third the lateral width of the segment. The terminal claw is about as long as the two preceding segments together, and is evenly tapering and slightly and evenly curved.

The radials are entirely concealed by the centro-dorsal in the median line, but their antero-lateral angles are visible inter-radially as small rounded tubercles, which usually are armed with exceedingly short fine spines. The I Br<sub>1</sub> are very short, crescentic, or band-like, becoming narrow laterally, in close lateral contact. Their surface is thickly covered with excessively fine spines which are often grouped on irregular pedicels suggesting paxillæ. The I Br<sub>2</sub> (axillaries) are about three times as broad as long, triangular or subrhombic, with the lateral angles truncated and in close lateral contact with those of their neighbours. The anterior edges are slightly thickened. The entire surface is thickly beset with excessively fine spines, which are more or less grouped on low irregular bases. The division series are broad, in close lateral contact, and sharply flattened laterally. They are only very moderately convex dorsally. The II Br series are 4(3+4).

The 11 arms are 80 mm. long. The first brachials are very short, four or five times as broad as the median length, half again as long exteriorly as interiorly, in close apposition and flattened against their fellows. The proximal and distal edges are slightly thickened and densely beset with excessively fine spines, which are also found more or less on the remainder of the dorsal surface. The second brachials are twice as large as the first, wedge-shaped, twice as long exteriorly as interiorly; the edges are slightly thickened and densely spinous, and the dorsal surface is more or less spinous. On the outer lateral edges of both the first and second brachials the spines become longer and are grouped on more or less prominent irregular bases. The first syzygial pair (composed of brachials 3+4) is more than twice as broad as long, oblong or slightly longer interiorly than exteriorly. The proximal and distal borders are everted and densely spinous and there is a double row of spines along the syzygial line, but otherwise the dorsal surface is free of spines. The next four brachials are slightly wedge-shaped, about three times as broad as long, with the edges, both proximal and distal, rather thickly everted and densely spinous, and numerous spines on the dorsal surface. The following brachials are triangular, about as long as broad, with the entire dorsal surface beset with very fine spines, which become longer on the slightly produced, but not overlapping, distal edge. Distally the brachials become wedge-shaped, as long as broad, and terminally longer than broad and ultimately elongate, while at the same time the spines on the dorsal surface become longer, more prominent, and more uniform in size, and are inclined so that they are directed diagonally outward from the arm.

$P_1$  is 8 mm. long with 20–21 segments, tapering evenly from the base to the slender tip. The segments at first are broader than long, becoming about as long as broad on the eighth and terminally longer than broad. The earlier segments have a broad band of fine spines on the distal edge, and after about the eighth the whole outer side becomes spinous in addition.

$P_2$  is somewhat shorter and more slender than  $P_1$ , and is composed of about 16 segments.  $P_3$  is very slightly shorter than  $P_2$ , with 16 segments. The genital pinnules have the fourth–seventh segments slightly broadened.

*Additional locality.*—South-east of Car Nicobar (lat.  $7^\circ 15' 24''$  N., long.  $92^\circ 59' 00''$  E.), cable-ship 'Patrol,' Eastern and Associated Telegraph Co.

*Notes.*—A smaller specimen from this locality is quite similar to the one described, though slightly smaller. It also has 11 arms, one II Br 4(3+4) series being present, all of which are broken off at the first syzygy. The cirri are XXI, 32–34, from 20 mm. to 23 mm. in length. The apical cirri are smaller and shorter than the peripheral, 15 mm. long, with 26 segments. The basal cirrus-segments have finely spinous ends, and a few short spines on the dorsal surface.



*Remarks.*—This new species is evidently most closely related to *Th. multi-spina* of the south Atlantic, from which it differs in the larger size, greater number of cirrus-segments, and less uniform distribution of spines on the dorsal surface of the ossicles of the division series.

**THALASSOMETRA MARGINATA A. H. Clark.**

*Thalassometra marginata* A. H. Clark, 1912, Crinoids of the Indian Ocean, 206.

*Locality.*—Nicobar Islands (lat.  $7^{\circ} 52' 38''$  N., long.  $92^{\circ} 59' 13''$  E.), C.S. 'Patrol,' Eastern and Associated Telegraph Co.

*Notes.*—One young specimen with 10 arms 35 mm. long was here secured.

**THALASSOMETRA ATTENUATA A. H. Clark.**

*Thalassometra attenuata* A. H. Clark, 1909, Proc. Biol. Soc. Washington, xxii, 147; Crinoids of the Indian Ocean, 1912, 204, fig. 38, 205.

*Locality.*—Off Mozambique (lat.  $16^{\circ} 48'$  S., long.  $39^{\circ} 40'$  E.), 500 fathoms, off a cable, C.S. 'Lady Denison-Pender,' Eastern and Associated Telegraph Co. One specimen.

**CROTALOMETRA ERIDANELLA, sp. n. (Pl. 42. fig. 9.)**

*Locality.*—Off Great Nicobar (lat.  $6^{\circ} 15'$  N., long.  $93^{\circ} 35'$  E.), 1040–1120 fathoms, C.S. 'Patrol,' Eastern and Associated Telegraph Co.

*Diagnosis.*—A species of *Crotalometra* in which the cirri, which are large and stout and composed of 45–57 segments, are arranged in ten columns on the centro-dorsal; the brachials beyond the proximal third of the arm have the distal edges strongly overlapping, the central portion of the distal edge often bearing an abrupt tuft or fin of rather long spines (more or less as in *C. sentifera*).

*Description.*—The centro-dorsal is hemispherical. The cirrus-sockets are arranged in ten columns, usually three to a column. There are two columns in each radial area, one along each side, where it is closely crowded against the column in the adjacent radial area. The central portion of each radial area is occupied by a bare sunken strip which is somewhat less in width than the breadth of the adjacent cirrus-sockets.

The cirri are about XXV, 45–57, large and stout, probably from 55 mm. to 60 mm. in length. The first segment is very short and those following increase in length to the sixth, which is about as long as broad, or slightly longer than broad, and still further increase to the tenth, a transition segment, which is about half again as long as broad. From the eleventh onward the segments gradually decrease in length so that those in the terminal third of the cirri are about twice as broad as long. On the tenth the dorsal portion of the distal edge is slightly produced, and as the segments become shorter this production of the distal edge extends proximally, and at the same time rises so that the short distal segments have a high dorsal carination with the rather abruptly rounded apex subterminal in lateral view.

In lateral view the cirri are stout basally, tapering noticeably in the first six or eight segments, increasing slightly in width beyond the tenth, and in the distal fourth tapering to a small tip.

The radials and part of the I Br<sub>1</sub> are concealed by the centro-dorsal, which in the inter-radial angles is extended anteriorly so as almost or quite to meet the lateral angles of the axillaries. The I Br<sub>1</sub> are short and crescentic, incised in the median line by the backward extension of the axillaries, and with the lateral borders reduced to a point. The I Br<sub>2</sub> (axillaries) are broad, rhombic, twice as broad as long, with the lateral angles truncated and the short sides thus formed flattened against those of the adjacent ossicles. Of the four II Br series present, two are 4(3+4) and two are 2. They are well rounded dorsally, but are in lateral contact. The borders and dorsal surface of the elements of the division series are entirely smooth, and there is only a very slight elevation at the synarthries.

The 14 arms were probably about 140 mm. long. The earlier brachials are broadly and evenly rounded dorsally and entirely smooth, with only a very slight eversion of the ends, which is very minutely, if at all, spinous. The position of the articular tubercles is faintly indicated. After the brachials become triangular, the production of the distal border becomes more marked and more prominently spinous, and on the brachials in the outer half of the arm there is a strong spinous overlap and the central portion of the distal edge of the brachials may bear an abrupt tuft or fin of rather long spines.

P<sub>1</sub> is 12 mm. long with 20 segments; it is fairly stout at the base and tapers evenly to a slender tip. The segments become about as long as broad on the fifth, and twice as long as broad on the thirteenth. The small elongated distal segments have spinous ends.

P<sub>2</sub> is 7 mm. long with 15 segments, proportionately smaller than P<sub>1</sub>. The segments become as long as broad on the third or fourth, and twice as long as broad on the tenth.

P<sub>3</sub> is shorter and less stout basally than P<sub>2</sub>.

The distal pinnules are 12 mm. long with 20-21 segments, of which the first is short, the second is half again as broad as long, the third is about as long as broad, and the outer are twice as long as broad. The dorsal keel on the segments is sharp and rather coarsely spinous, and there is a little tuft of spines at the end of each segment.

### Family CHARITOMETRIDÆ.

*PERISSOMETRA OCCIDENTALIS*, sp. n. (Pl. 42. fig. 10.)

*Locality*.—One hundred and twenty miles off the Seychelles, 800 fathoms, cable-ship 'Lady Denison-Pender,' Eastern and Associated Telegraph Co.

*Diagnosis.*—A species of *Perissometra* in which the proximal portion of the animal is not constricted; there are not more than 15 arms; the cirri are XXV, 15–18, moderately stout, with several of the segments about as long as broad.

*Description.*—The centro-dorsal is large, truncated conical, with the cirrus-sockets arranged in ten closely crowded columns of usually three each.

The cirri are about XXV, 15–18, moderately stout, the longest from 30 mm. to 35 mm. in length. The first segment is very short, the second is longer, the third is about twice as broad as long, the fourth is nearly as long as broad, and the fifth is about one-third again as long as broad on the longest peripheral cirri, and very slightly longer than broad on the other cirri. The following segments decrease in length so that the last seven or eight before the penultimate are about as long as broad. The penultimate segment is narrower than those preceding, and in lateral view is from one-third to one-half again as long as broad. From the fifth onward the segments in lateral view have slightly diverging ventral and dorsal edges, and their distal ends slightly overlap the bases of the segments succeeding. On the dorsal side, the distal end of the segments may be thickened so as to project considerably beyond the base of the succeeding segments, giving the dorsal profile of the outer portion of the cirri a low and roundedly serrate appearance. The opposing spine, which arises from the conspicuous white terminal band on the penultimate segment, is transversely broadened, with the crest chisel-shaped or strongly bilobate.

The ends of the basal rays are visible as prominent rhombic tubercles in the inter-radial angles.

The radials are entirely concealed by the centro-dorsal. The I Br<sub>1</sub> are very narrow and band-like, usually quite concealed by the centro-dorsal except for a rounded medial tubercle and the very narrow and irregular lateral portions, which extend diagonally outward, meeting those of the adjacent I Br<sub>1</sub> above the ends of the basal rays. The borders of these lateral portions are sinuate, and the distal angle is usually produced inwardly in the form of a conspicuous tooth, which fits into a corresponding cavity beneath the lateral angle of the axillary. The I Br<sub>2</sub> (axillaries) are broadly rhombic, with the lateral angles slightly truncated forming short sides, which are about as long as the width of the lateral portions of the I Br<sub>1</sub>. The median portion of the axillaries is elevated, rising regularly into a very broadly rounded tubercle with the maximum height in about the proximal third. The proximal border of the axillary, except in the median line, is produced into a flange-like extension with a sinuous and more or less irregular edge, the irregularities fitting into corresponding irregularities in the adjacent border of the I Br<sub>1</sub>. There are five II Br series present, four of these being 4(3+4) and one being 2. The division series are smooth dorsally and rise

evenly to a very broadly convex central portion. They are closely appressed against their neighbours. The  $II\ Br_1$  are very short, and their inner portion is extended distally and is terminated by a short side at right angles to the lateral edge, which is usually more or less produced inwardly in the form of a tooth fitting into a notch in the  $II\ Br_2$ .

The 15 arms are about 130 mm. long. The first brachials are very short, five or six times as broad as long, with the inner portion curving about and extending to beyond the middle of the second brachial, where it is bounded by a line at right angles to the lateral edge. The inner corner of this distal border is extended in the form of a more or less pronounced tooth which fits deeply into a corresponding excavation in the side of the second brachials. The second brachials are about twice as long as the first. They are irregularly half-moon shaped, as a result of the overlapping of their proximal portion by the distal extensions of the first brachials, but their inner angles are somewhat abruptly produced over the ends of these processes, coming into lateral contact. The lateral borders of the first two brachials are slightly turned outward. On arms arising directly from a  $I\ Br$  axillary, the first syzygial pair (composed of brachials 3 + 4) is about three times as broad as long, oblong, but with the proximal and distal borders broadly sinuous. The next seven brachials are wedge-shaped, about three times as broad as the median length, and those following become triangular, about as long as broad, and wedge-shaped again in the outer portion of the arms.

$P_1$  is 12 mm. long and is composed of 30 segments. It is rather stout at the base, but tapers evenly and rather rapidly so that the distal fourth is slender and delicate. The first segment is large, much broader than long, and is extended distally both at the dorsal and ventral angles so as to overlap for some distance the proximal angles of the second. The second segment is scarcely two-thirds as broad as the first, not quite twice as broad as long, its distal dorsal and ventral angles are extended slightly forward, and are more or less blunted or rounded off. The third segment is similar, but the distal processes are shorter and more broadly rounded. The following segments have the outer portion of the distal border curved toward the pinnule-tip. The segments increase in length very slowly, not becoming as long as broad until very near the pinnule-tip. All of the segments, except those at the extreme end of the pinnule, are somewhat produced dorsally and sharply carinate.

$P_2$  is 13 mm. long, stouter than  $P_1$ , and tapering more gradually so as to lack the delicate tip. It is composed of 25 segments, which become as long as broad on the twelfth and somewhat longer than broad terminally.

$P_3$  is 13 mm. long with 20 segments, tapering still more gradually than  $P_2$ . The segments become as long as broad on about the twelfth, and slightly longer than broad distally.

On the genital-pinnules the third, fourth, and fifth segments are somewhat enlarged and broadened to protect the gonads.

The distal pinnules are 13 mm. long with about 16 segments, most of which are from half again to twice as long as broad.

*Remarks.*—This new form is most closely related to *P. crassa*, but the cirri are less stout with fewer segments, and the whole animal is less robust.

**PERISSOMETRA GORGONIA** A. H. Clark.

*Perissometra gorgonia* A. H. Clark, 1918, The Unstalked Crinoids of the 'Siboga' Exped. 179.

*Locality.*—South of the Nicobar Islands, 560 fathoms, cable-ship 'Patrol,' Eastern and Associated Telegraph Co.

*Notes.*—A very large and badly broken specimen, with apparently 20 arms, I refer with some hesitation to this species. The cirri have 17–22 segments. The edges of the ossicles of the division series and brachials are much less prominent than in the type, while there is scarcely an indication of the median tubercle beyond the lowest brachials. One of the II Br series is 2, the remainder being 4(3+4).

With this there is a very small specimen with 11 arms 50 mm. long, one II Br 4(3+4) series being developed.

**PERISSOMETRA MACILENTA** (A. H. Clark).

*Pachylometra macilenta* A. H. Clark, 1909, Proc. Biol. Soc. Washington, xxii, 81; 1912, Crinoids of the Indian Ocean, 222, fig. 41, 223.

*Locality.*—South of Timorlaut (lat. 11° S., long. 131° 30' E.), 500 fathoms, C.S. 'Patrol,' Eastern and Associated Telegraph Co.

*Notes.*—The single specimen has 14 arms about 150 mm. long.

**CRINOMETRA BREVIPINNA** (Pourtales).

*Comatula brevipinna* Pourtales, 1868, Bull. Mus. Comp. Zool. i, No. 6, p. 111.

*Locality.*—Off St. Thomas, Virgin Islands, 240 fathoms (*Capt. A. Morrell*, 1913). One specimen.

**GLYPTOMETRA TUBEROSA** (P. H. Carpenter).

*Antedon tuberosa* P. H. Carpenter, 1888, 'Challenger' Reports, Zool. xxvi, part 60, p. 126, pl. 14, fig. 9; pl. 23, fig. 2.

*Locality.*—Between Cebu and Leyte, Philippines (lat. 11° 07' N., long. 124° 06' E.), 154 fathoms. One 10-armed specimen.

Family **ANTEDONIDÆ**.

Subfamily **ANTEDONINÆ**.

**COMPSOMETRA SERRATA** (A. H. Clark).

*Antedon serrata* A. H. Clark, 1908, Bull. Mus. Comp. Zool. ii, no. 8, p. 240, pl. 1, fig. 4.

*Locality.*—Cape Sima, Japan (*Dr. G. Jeffreys*). One small specimen.

**ANNAMETRA OCCIDENTALIS** (A. H. Clark).

*Cominia occidentalis* A. H. Clark, 1915, *Die Crinoiden der Antarktis*, 164, pl. 10, figs. 1-5.

*Locality*.—Durban, Natal, 1906. One specimen.

**TOXOMETRA PAUPERA** A. H. Clark.

*Toxometra paupera* A. H. Clark, 1911, *Proc. U.S. Nat. Mus.* xxxix, 560.

*Locality*.—Between Cebu and Leyte, Philippines (lat. 11° 07' N., long. 124° 06' E.), 154 fathoms. One small specimen.

**IRIDOMETRA MAXIMA**, sp. n. (Pl. 43. figs. 12, 13.)

*Locality*.—Rotti Strait, 100 fathoms, U.S. 'Cable,' Eastern and Associated Telegraph Co., from the Banjuwangi-Darwin No. 2 cable.

*Diagnosis*.—A very large and robust species of *Iridometra* in which the centro-dorsal is large and hemispherical, with a deeply concave dorsal pole; the arms are about 95 mm. long; the cirri are L-LV; P<sub>1</sub> is 12 mm. long with 13-14 segments; P<sub>2</sub> is 13 mm. long with 13-14 segments; and P<sub>3</sub> is from 11 mm. to 14 mm. long with 15-16 segments.

*Description*.—The centro-dorsal is hemispherical, 5 mm. in diameter at the base and 3 mm. high, with a deeply sunken papillose dorsal pole, about 2 mm. in diameter. The cirrus-sockets are arranged in four and a partial fifth closely crowded alternating rows, the size of the sockets decreasing gradually from the proximal to the apical rows.

There are between L and LV cirrus-sockets. All of the cirri are lost.

The radials are short, from four to six times as broad as long; their antero-lateral angles are separated by a notch. The diameter of the radial ring is slightly less than that of the centro-dorsal, so that the latter has a knob-like appearance. The I Br<sub>1</sub> are short, five or six times as broad as long in the median line, trapezoidal, with the lateral borders converging slightly distally. The I Br<sub>2</sub> (axillaries) are broadly pentagonal, half again as broad as long. The lateral sides are short, shorter than those of the I Br<sub>1</sub>, and make with these a broadly obtuse angle. The anterior angle is approximately a right angle, and the anterior sides are only slightly concave.

The 10 arms are about 95 mm. long. The first brachial is short, twice as long exteriorly as interiorly, interiorly united in the proximal half, the distal half of the inner border making with the proximal half a right angle, so that the distal halves of the inner edges of two adjacent first brachials lie in the same straight line. The second brachials are usually nearly twice as large as the first, and are irregularly quadrate in shape. The first syzygial pair (composed of brachials 3 + 4) is wedge-shaped, almost twice as long interiorly as exteriorly and twice as broad as the median length. The next four brachials are very short, twice as broad as the maximum and four times as

broad as the median length, wedge-shaped, with concave proximal and distal ends. After the second syzygy, the brachials soon become triangular with gently concave distal borders, and about one-third broader than long. After the proximal third of the arm, the brachials gradually become wedge-shaped, at about the middle of the arm becoming about as long as broad and terminally elongate.

Syzygies occur usually between brachials 3 + 4, 9 + 10, and 14 + 15, and distally at intervals of from 2 to 5, most commonly 3 or 4, muscular articulations. The second syzygy is sometimes omitted, and the position of the third is subject to some irregularity.

$P_1$  is 12 mm. long with 13 or 14 segments, and is considerably stiffened. The first segment is about as long as broad, the second is slightly trapezoidal, from half again to nearly twice as long as the width of the narrower distal end, the third is twice as long as broad or slightly longer, very slightly constricted centrally, the fourth is three times as long as broad, the sixth and seventh are the longest, from three to four times as long as broad, and the remainder are slightly shorter. The earlier segments are entirely smooth. On the sixth there is a slight eversion of the distal edge which on the eighth and following becomes a conspicuous strongly dentate overlapping frill.  $P_2$  is 13 mm. long with 13 or 14 segments, resembling  $P_1$ , but tapering more gradually and hence slightly stouter.  $P_3$  on some arms is 14 mm. long with 16 segments, slightly stouter than  $P_2$ , but on other arms 11 mm. long with 15 segments and slightly less stout than  $P_2$ .  $P_4$  is 9 mm. long with 14 segments, on some arms resembling the preceding pinnules, but less stiffened and much more slender, and on other arms resembling  $P_2$ . The next two pinnules are similar in length and number of segments to  $P_4$ , but are slightly stouter basally, less stiffened, and have the ends of the outer segments less conspicuously everted. The distal pinnules are 12 mm. long with 17 or 18 segments, which in the outer portion become about four times as long as broad.

*Remarks.*—In its general appearance this species may be described as having the brachial structure of a very large species of *Antedon*, with a centro-dorsal resembling that of *Heliometra*.

Its much larger size and more robust build give it an appearance quite different from that of the other species of *Iridometra*, but the agreement in structure is so very close that it would scarcely be advisable to create another genus for it.

#### EUMETRA APHRODITE A. H. Clark.

*Iridometra (Eumetra) aphrodite* A. H. Clark, 1912, Notes from the Leyden Mus. xxxiv, 137.

*Locality.*—Macclesfield Bank, 35–41 fathoms. One specimen.

## Subfamily ZENOMETRINÆ.

*SARAMETRA NICOBARICA*, sp. n. (Pl. 43. fig. 11.)

*Locality*.—Off the Nicobar Islands, on the Madras-Penang cable, U.S. 'Patrol,' Eastern and Associated Telegraph Co.

*Diagnosis*.—A species of *Sarametra* in which the centro-dorsal, which is wholly without spines, is more than half again as high as broad at the base, and its radial areas carry from three to four columns of cirrus-sockets; the spines on the ossicles of the division series and on the brachials are short, and are confined to the borders of the ossicles, and there is a slight development of synarthrial and articular tubercles.

*Description*.—The centro-dorsal is elongate-conical, 8.5 mm. high by 5 mm. broad at the base. For about the basal third the sides converge somewhat less rapidly than from that point onward. The tip is unusually acute. The sides are divided into five radial areas by bare inter-radial lines, which are not raised above the general surface of the centro-dorsal except in one inter-radial area, where the median portion of the bare lines forms a low and inconspicuous ridge. These lines are at first from half as wide to quite as wide as the adjacent cirrus-sockets, but gradually narrow and become obsolete somewhere between the basal half and terminal third of the centro-dorsal. Two of the radial areas contain proximally four closely-crowded columns of cirrus-sockets, the sockets of one column alternating with those of the columns on either side; between the end of the proximal third and half of the centro-dorsal these four columns of cirrus-sockets pass over into three. Another radial area has proximally three columns, and along the right-hand border a few sockets representing a fourth column, and the two remaining radial areas have three columns of sockets from base to apex. There are thirteen or fourteen sockets to a column, of which the proximal 4 to 6, which are larger and better formed than the others, alone appear to have been functional. But well-formed sockets continue to the apex of the centro-dorsal, which is wholly without spines.

None of the cirri are preserved beyond the base. The longest stump remaining consists of three segments which do not differ from those in the largest cirri of *S. triserialis*.

The ends of the basal rays are prominent as tubercles in the inter-radial angles bridging over the regions between the shallow subradial clefts.

The surface and distal border of the radials are wholly without spines. The division series and arms resemble those of *S. triserialis*, but are proportionately stouter and also more rugged, with a slight development of synarthrial and articular tubercles. The animal is much less spinous than *S. triserialis*. The spines on the proximal and distal edges of the elements of the division series and lower oblong brachials, though very numerous, are short. The lateral borders of the axillaries and of the second brachials bear



a series of webbed spines which are much longer than those found elsewhere. The outer brachials have a group of long and very closely set spines in the middle of the distal border, but much shorter spines elsewhere.

$P_1$  is 8 mm. long with about 17 segments, of which the first is nearly half again as long as the maximum width, the second and third are somewhat shorter, the fourth is half again as long as broad, the fifth is twice as long as broad, and the remainder are greatly elongated. The pinnule is slender, gradually tapering, and becomes filiform in the outer portion. The first three segments have the corners on the side turned toward the arm very broadly rounded off.

$P_2$  is about 10 mm. long with about 15 segments, resembling  $P_1$ , but slightly less slender.  $P_3$  is slightly longer than  $P_2$ , stouter and less flexible, and tapering more gradually.

#### Subfamily HELIOMETRINÆ.

##### PROMACHOCRINUS KERGUELENSIS P. H. Carpenter.

*Promachocrinus kerguelensis* P. H. Carpenter, 1888, 'Challenger' Reports, Zool. xxvi, part 60, 350, pl. 1, figs. 1 a-d; pl. 70.

*Locality*.—'Terra Nova' station 341. One large specimen.

##### ANTHOMETRA ADRIANI (Bell).

*Antedon adriani* Bell, 1908, Nat. Antarctic Exped. iv (Echinoderma), 4, pl. 2.

*Locality*.—'Terra Nova' station 314. Four specimens.

*Discovery*.—No. 10 hole. Two very small specimens.

#### Subfamily BATHYMETRINÆ.

##### TONROMETRA MULTICIRRA, sp. n. (Pl. 42. fig. 8; Pl. 44. fig. 16.)

*Locality*.—South of Lombok, Lesser Sunda Islands (lat.  $9^{\circ} 06' 15''$  S., long.  $116^{\circ} 27' 10''$  E.), 700 fathoms, C.S. 'Cable,' Eastern and Associated Telegraph Co.

*Diagnosis*.—A large species of *Tonrometra* in which the arms are about 45 mm. long, and the cirri are about XL, 25–28, about 12 mm. long, with the longest segments (the fourth–fifth) about half again as long as broad.

*Description*.—The centro-dorsal is apparently rounded conical, and is almost completely covered with cirrus-sockets, which decrease markedly in size from the periphery to the apex.

The cirri are about XL, 25–28, about 12 mm. long. The apical cirri are about one-fourth the length of the peripheral, slender and delicate, with 14 segments. In the long peripheral cirri the first segment is short, the second is half again as broad as long, the third is one-third again as long as broad, and the fourth and fifth are the longest, about half again as long as broad.

The following segments decrease in length, becoming as long as broad on the ninth and very slightly broader than long in the terminal third of the cirri. The second-fourth segments are somewhat constricted centrally with flaring and slightly overlapping distal ends, this feature soon dying away distally. The outer segments which are no longer than broad—that is, the segments from the seventh, eighth, or ninth onward—have a rather broad median carination in the mid-dorsal line, the crest of which is in profile at first evenly convex, the maximum height of the convexity later becoming sub-terminal. The opposing spine is prominent, conical, arising from the entire dorsal surface of the penultimate segment, with the apex median to sub-terminal. The terminal claw is rather stout, slightly longer than the penultimate segment, and strongly curved. In the small apical cirri the longest earlier segments are about half again as long as broad, and the outer are about as long as broad.

The distal border of the radials is even with the rim of the centro-dorsal. The  $I\ Br_1$  are short with strongly converging lateral borders and the distal border incised by the posterior projection from the axillary. The  $I\ Br_2$  (axillaries) are broadly pentagonal, about as long as broad. The lateral edges are about as long as those of the  $I\ Br_1$ , with which they make a broadly obtuse angle.

The 10 arms are about 45 mm. long. The first brachials are very short, wedge-shaped, from two to three times as long exteriorly as interiorly, interiorly united in the basal third, the inner sides diverging at an obtuse angle from the point of contact. The second brachials are rather more than twice as large as the first, and are irregularly quadrate in shape. The first syzygial pair (composed of brachials 3 + 4) is somewhat broader than long. The next four brachials are slightly wedge-shaped, about twice as broad as the median length. After the second syzygy the brachials become triangular, slightly longer than broad, and soon very obliquely wedge-shaped and longer than broad, becoming still more elongate distally. The distal ends of the brachials are not produced or modified.

Syzygies occur between brachials 3 + 4, 9 + 10, and 14 + 15, and distally at intervals of two muscular articulations.

$P_1$  is 4.5 mm. long, exceedingly slender, with 16 segments, of which the first is much broader than long, the second is broader than long, the third is nearly as long as broad, the fourth is longer than broad, and those following rapidly become greatly elongated with expanded and finely spinous distal ends.

$P_2$  resembles  $P_1$ , but is slightly stouter basally and somewhat shorter, with 14 segments, of which the second is as long as broad, and the third is longer than broad.

$P_3$  is markedly stouter than the preceding pinnules, and appears to be slightly shorter than  $P_2$ .

*Remarks.*—This new form appears to be related to *T. remota*, from which it is distinguished by its more numerous cirri, which have more numerous segments.

### Family NOTOCRINIDÆ.

#### NOTOCRINUS VIRILIS Mortensen.

*Notocrinus virilis* Mortensen, 1918, *Wiss. Ergeb. d. schwed. Südpolar Exped.* 1901–1903, vi, *Lief.* 8 (1918), p. 2, pl. 1, figs. 1–5; pl. 2, figs. 1–4; pls. 3–4.

*Locality.*—‘Terra Nova’ station 341. One specimen, with the arms about 160 mm. long.

### EXPLANATION OF THE PLATES.

#### PLATE 40.

- Fig. 1. *Iconometra speciosa*, sp. n., the type-specimen.  $\times 2$ .  
 2. *Iconometra speciosa*, sp. n., the type-specimen viewed from the other side, with a post-radial series removed to show the pinnules.  $\times 2$ .  
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 4. *Thalassometra peripolos*, sp. n., the lower portion of a post-radial series from the type-specimen, showing the proximal pinnules.  $\times 2$ .

#### PLATE 41.

- Fig. 5. *Stenometra diplax*, sp. n., the type-specimen.  $\times 2$ .  
 6. *Parametra ajax*, sp. n., the type-specimen. Natural size.  
 7. *Parametra ajax*, sp. n., a detached post-radial series from the type-specimen, showing the proximal pinnules. Natural size.

#### PLATE 42.

- Fig. 8. *Tonrometra multicirra*, sp. n., the type-specimen.  $\times 2$ . (See also Pl. 44. fig. 16.)  
 9. *Crotalometra eridanella*, sp. n., the type-specimen. Natural size.  
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#### PLATE 43.

- Fig. 11. *Sarametra nicobarica*, sp. n., the type-specimen.  $\times 2$ .  
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- Fig. 14. *Decametra alaudæ* A. H. Clark, the specimen described.  $\times 2$ .  
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3

4

SOME RECENT CRINOIDS





SOME RECENT CRINOIDS.





SOME RECENT CRINOIDS







SOME RECENT CRINOIDS.





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SOME RECENT CRINOIDS.



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